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Volume 12, Number 4, April 1971

Radiological Health Data and Reports, a monthly publication of the Environmental Protection Agency, presents data and reports provided by Federal, State, and foreign governmental agencies, and other cooperating organizations. Pertinent original data and interpretive manuscripts are invited from investigators.

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels. This responsibility was delegated to the Bureau of Radiological Health, Public Health Service. Pursuant to the Reorganization Plan No. 3 of 1970, effective December 2, 1970, this responsibility was transferred to the Radiation Office of the Environmental Protection Agency which was established by this reorganization.

The Federal agencies listed below appoint their representatives to a Board of Editorial Advisors. Members of the Board advise on general publications policy; secure appropriate data and manuscripts from their agencies; and review those contents which relate to the special functions of their agencies.

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ENVIRONMENTAL PROTECTION AGENCY
William D. Ruckelshaus, Administrator

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Reports

Dose Assessment of Ionizing Radiation Exposure to the Population

Michael S. Terpilak, Charles L. Weaver, and *Samuel Wieder*[1]

The population dose from natural background, residual weapons test fallout, nuclear power operations, and medical and dental uses of ionizing radiation has been reviewed. Reported and projected population exposures from these sources indicate that, for the near future, the predominant exposure to the public will be attributable to natural background and to medical x rays. A continual evaluation to assess priorities, based on magnitude and type of exposure, and investigations into the biological effects of radiation constitute important features of public health responsibility.

A declining trend is in prospect for exposure to weapons test fallout in the absence of major atmospheric nuclear explosions. Exposure resulting from all procedures related to nuclear power operations and from diagnostic medical radiation (x rays and internally administered radionuclides) is projected to become of increasing importance. These warrant increased attention in planning for surveillance. Surveillance associated with peaceful uses of nuclear explosions (Plowshare Program) and with tests of nuclear engines for propulsion requires individual programming.

The assessment of total population exposure to ionizing radiation requires consideration of all sources of such exposure, natural and man-made. A substantial amount of information is available about the population dose from natural background, residual fallout from nuclear weapons tests, and medical and dental x rays. The population dose from operations of nuclear reactors, nuclear fuel reprocessing plants, and other sources of ionizing radiation is currently being studied and ranges of exposure are being estimated. Public health agencies will increasingly direct their activities to the evaluation of potential health effects of radioactive releases from the operations of an expanding nuclear industry, including the peaceful applications of nuclear explosions.

A staff study was made to evaluate the population exposure from the sources listed in table 1. This report presents the findings of this review and suggests some implications relative to the operational program of the Division of Surveillance and Inspection, Radiation Office. In this presentation, it is convenient to distinguish between exposure from natural sources, that from man-made sources excluding environmental contamination, and that from environmental contamination.

Table 1. Sources of irradiation

A. Irradiation from natural sources
  1. Cosmic rays
  2. Radiation from naturally occurring radioactive materials

B. Irradiation from man-made sources excluding environmental contamination
  1. Medical irradiation due to:
    a. Diagnostic x-ray procedures
    b. Radiotherapy (external or from sealed sources)
    c. Internally administered radioisotopes
  2. Occupational irradiation
  3. Irradiation from consumer devices

C. Irradiation from radioactive contamination of the environment due to:
  1. Explosions of nuclear weapons
  2. Operating nuclear facilities
  3. Peaceful uses of nuclear explosives

Natural sources

Natural radiation exposure originates from interactions of primary cosmic rays with the earth's atmosphere and from the radioactive decay of naturally occurring radionuclides. These radionuclides contribute both an external and an internal exposure.

---

[1] Mr. Terpilak is acting assistant director, and Mr. Weaver is acting director, Division of Surveillance and Inspection. Mr. Wieder is editor, *Radiological Health and Reports*, Division of Surveillance and Inspection, Radiation Office, Environmental Protection Agency, Rockville, Md.

Cosmic rays

Primary cosmic rays are of extraterrestrial origin and interact with the upper layers of the atmosphere, producing secondary rays (both electromagnetic and particulate radiation) to which all living beings are exposed (*1*). These secondary rays contribute about one-third of the natural external radiation at sea level. Higher contributions from both primary and secondary rays occur at very high altitudes (*2*).

The dose rate from cosmic rays at sea level is about 30 mrem/a and varies about 10 percent at sea level (*1–3*). The rate is, however, much higher in areas of high altitude. The exposure nearly doubles for each 1.5 kilometer increase in altitude up to about 7 kilometers. At altitudes above about 8 kilometers, the dose rate increases more rapidly. Populations living at 3 kilometers (10,000 feet) could receive a cosmic ray dose about four times that received by those living at sea level (*4*). Cosmic radiation measurements made in major cities in the United States showed ranges from less than 4 μR/h in coastal areas to nearly 9 μR/h in some cities in Colorado and Wyoming (*5*).

Terrestrial irradiations

The naturally occurring radionuclides which contribute significantly to the external irradiation of man are the uranium-238 and thorium-232 daughters. These nuclides are present practically everywhere, but their abundance varies widely from area to area. It is estimated that the average external exposure from terrestrial gamma rays to which the population is exposed, ranges from 25 to 75 mR/a.

In certain areas where the soil is particularly rich in radioactive ore, such as alluvial deposits of monazite, population exposure rates are much higher. In the Brazilian states of Espirito Santo and Rio de Janeiro, about fifty thousand people who dwell on deposits of this thorium-bearing mineral receive from 0.5 to 1.0 R/a. Elsewhere in Brazil, in the states of Minas Gerais and Goias, mineralized volcanic intrusives containing radioactive minerals are present. In one village of 350 people, these minerals produce exposures up to 12 R/a. In the areas of Kerala and Madras (India) where nearly one-hundred-thousand people live, the exposure to these inhabitants varies from 0.2 to 2.6 R/a (*4*). These appear to be the only densely populated areas where the irradiation from naturally occurring radionuclides is known to be so high. Some population groups are also exposed to higher than average radon-222 levels due to local climatic conditions (frequent inversions).

Total external natural exposure

Solon et al. (*5*) undertook an extensive series of measurements throughout the United States and found that the external environmental radiation exposure rates in populated areas ranged from 73 mrad/a in New Haven, Conn., to 197 mrad/a at Colorado Springs, Colo. Other studies on measurements of natural background gamma radiation showed average exposure rates ranging from 5.1 μrad/h near Facil, Fla., to 14.6 μrad/h in Fort Morgan, Colo. (*6*). These studies were made in areas away from man-made surfaces to avoid the effects of disturbed soil or building materials. In addition, an altitude correction was included in the calibration formula to adjust for the lower sensitivity of the instrument to high energy cosmic radiation, which increases at higher elevations.

Internal exposure

Air, drinking water, and food contain variable amounts of radioactive material of natural origin which may be deposited in the body after ingestion or inhalation. The main natural radioactivity of the body arises from elements of the uranium and thorium decay series and from potassium-40 and carbon-14. Internal dose rates from natural sources of radioactivity in "normal" areas of the world have been summarized by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (*2*) and are shown in table 2. It has not been possible to assess accurately the variability of dose rates received by different populations, but the major component, potassium-40, is a constant fraction of total potassium worldwide, giving doses that depend on body composition of muscle, fat, and bone.

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Table 2. Dose rates due to internal irradiation from natural sources in "normal" areas

Source of irradiation	Dose rates (mrad/a)	
	Gonads	Bone marrow
Potassium-40	20	15
Rubidium-87	.3	<0.3
Carbon-14	.7	1.6
Radium-226	....	.03
Radium-228	....	.03
Polonium-210	.3	.3
Radon-222 (dissolved in tissues)	.3	.3
Total[a]	22	18

[a] Rounded to 2 significant figures.

Man-made sources excluding environmental contamination

Medical exposure

This category consists of those irradiations which are administered to patients by radiolologists, general practitioners, dentists, etc., for diagnostic or therapeutic purposes. Radiological procedures in medicine are finding increasing use. At the same time, however, these procedures require continuing consideration of both medical benefits and radiation risks.

Diagnostic x-ray procedures

The 1964 X-Ray Exposure Study conducted by the Bureau of Radiological Health was designed to produce estimates of the magnitude of x-ray exposure to the U.S. population. The number of persons x-rayed, types of examinations, and exposure from these examinations were published in a report, "Population Dose from X-rays, U.S. 1964" (*7*). The genetically significant dose is defined as the gonad dose which, if received by every member of the population, would result in the same total genetic effect to the population. This definition is based upon the following assumptions and considerations:

1. The relevant tissue dose is the accumulated dose to the gonads;
2. The individual gonad dose is weighted with a factor which takes into account future number of children expected of the irradiated individual compared with an average member of the population (in this connection, the fetus is treated as such an irradiated individual and not as the child of an irradiated parent).

The genetically significant dose for the U.S. population (1964) was found to be 55 millirads per person per year. The genetically significant dose from dental procedures was well below 1 millirad (*7*).

External radiotherapy

In therapy, not only x rays but also beta and gamma rays are used, the latter provided either by application of sealed isotopes (for instance, radium or strontium-90 plaques) or by exposure to cobalt and cesium teletherapy units (*1*). The available estimates of the population average genetically significant doses from external radiotherapy for nonmalignant conditions in four European countries ranged from 2.2 to 4.5 mrem/a (*1*). These are much lower than the genetically significant doses due to diagnostic procedures. The frequency of therapeutic irradiations is, however, very much lower than the frequency of diagnostic irradiations, and the child expectancy of the therapy patients is often lower.

Since radiotherapy is used in the treatment of nonmalignant and malignant conditions, it is necessary to evaluate in any consideration of genetically significant dose, the effect of the disease itself and also of the irradiation on the relative child expectancy. It may be assumed that neither the nonmalignant conditions nor the radiation doses, with the possible exception of those in the regions of the gonads, affect the fertility of patients. However, for patients suffering from malignant conditions, the life expectancy is usually shorter than in the general population, and in each age group of such patients a less number of children will be conceived as compared to the statistics for the whole population (*1*). The UNSCEAR publication cites an estimate by Clark that the annual per capita dose to the total United States population from external radiotherapy is 12 mrem. He assumed that the gonad doses from irradiation for malignant conditions were of no genetic significance. In Austrialia, Martin estimated the annual genetically significant dose from external radiotherapy to be 28 mrem (*1*). These values were employed in the Federal Radiation Council

(FRC) Report No. 1 and reported as average annual genetically significant doses to the population (*3*).

Thus, available estimates of genetically significant doses due to external radiotherapy range up 28 mrem/a; additional work is required to refine the dose estimates.

In recent reports (*8-9*), the use of brachytherapy and teletherapy procedures was surveyed. In 1966, it was estimated that about 50,000 patients received brachytherapy. It can be seen from table 3 that radium is the most widely used of the eight radionuclides listed, accounting for 58 percent of the total number of treatments.

The survey results for teletherapy procedures are summarized in table 4. The data show that 157,078 patients received a total of 1,919,948 teletherapy administrations, for an average of about 12 administrations per patient. The only condition reported as treated by teletherapy was cancer. Ninety-seven percent of the treatments used cobalt-60; the remainder used cesium-137.

Internally administered radioisotopes

Internally administered radioisotopes are used both for diagnostic and therapeutic purposes and are applied on an increasing scale because of their greater availability, improved techniques, and better understanding of physiology and biochemistry. The use of these materials, generally designated as radiopharmaceuticals, has not only increased but has also undergone changes with respect to choices of the radioactive element used or of the isotope of a given element. For example, between 1959 and 1966, the relative frequency of the use of iodine-131 declined, while the use of iodine-125 increased. Similarly, the use of radiopharmaceuticals labeled with cobalt-60 declined, while those labeled with cobalt-57 increased. Such substitutions are made for reasons of reduction of radiation dose and improved diagnostic effectiveness. Additionally, radioelements such as technetium-99m, selenium-75, and indium-113m have found increasing use in diagnosis, and the radioactive noble gases, xenon-133 and krypton-85, are

Table 3. Principal brachytherapy procedures reported by respondents to survey during 1966[a]

Radionuclide	Composition	Procedure	Physicians licensed for procedure	Physicians performing procedure	Patient administrations	
					Number	Percent
^{226}Ra	Sealed sources	Intracavitary Rx of cancer	734	543	15,700	31.6
^{90}Sr	Eye applicator	Ophthalmic treatment	483	295	11,785	23.7
^{226}Ra	Plaques and moulds	Dermatological treatment	378	109	5,582	11.2
^{226}Ra	Needles	Interstitial Rx of cancer	604	276	4,152	8.4
^{222}Rn	Seeds	Interstitial Rx of cancer	436	158	3,069	6.2
^{60}Co	Needles or seeds	Intracavitary Rx of cancer	283	90	2,737	5.5
^{226}Ra	Nasopharyngeal applicator	Intracavitary Rx of cancer	306	50	2,457	5.0
^{90}Sr	Plaques	Dermatological treatment	8	7	1,182	2.4
^{90}Sr	Nasopharyngeal applicator	Nonmalignant conditions	6	6	678	1.4
^{137}Cs	Sealed sources	Intracavitary Rx of cancer	22	16	548	1.1
^{60}Co	Needles, wire, and so forth	Interstitial Rx of cancer	258	31	547	1.1
^{192}Ir	Seeds—nylon ribbon	Interstitial Rx of cancer	51	32	404	.8
^{226}Ra	Nasopharyngeal applicator	Nonmalignant conditions	18	12	383	.8
^{198}Au	Seeds	Interstitial Rx of cancer	20	12	106	.2
^{226}Ra	Eye applicator	Ophthalmic treatment	7	6	100	.2
Total for principal procedures listed above					49,430	99.6
Total for 9 other procedures with less than 100 administrations					192	0.4
Total for all brachytherapy procedures					49,622	100.0

[a] Comprises responses from less than 50 percent of mailed questionaires.

Table 4. Principal teletherapy procedures reported by respondents to survey during 1966[a]

Radionuclide	Procedure	Physicians licensed for procedure	Physicians performing procedure	Patients	Patient administrations	
					Number	Percent
^{60}Co	Beam therapy	524	399	153,714	1,859,845	97
^{137}Cs	Beam therapy	76	25	3,364	60,103	3
Total for all teletherapy procedures				157,078	1,919,948	100

[a] Comprises responses from less than 50 percent of mailed questionaires.

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used in studies on the circulatory system (*9*).

The number of admininstrations of radioisotopes for medical reasons in the United States has been variously estimated at 270,000 (*1*) and 400,000 (*9*) for 1959. By 1966, this rate had increased to about 1,500,000 (*9*) (see, however footnotes to tables 3 and 4), and a more recent estimate (*10*) indicated that by 1970 there were some 8,000,000 administrations of radioisotopes annually for treatment and diagnosis.

Calculations of dose, and particularly of genetically significant dose, from the use of internally administered radionuclides are difficult. A schema for such calculations for individual administrations has been published (*11*). Dose assessment depends on a large number of variables, including: the amount, purity, carrier, and chemical form of the radionuclide; distribution, metabolism, energy spectrum, and half-times of the radioactive material at the total-body, organ, and sub-organ levels; and the influence of the patient's age, body structure, and clinical status on the distribution and elimination of the radionuclide.

In a symposium on medical radionuclides, considerations of dosimetry and radiation effects were discussed for the various kinds of radionuclide administration (*12*). Principles and procedures for calculating absorbed dose were presented by a number of investigators (*13–16*).

The increased rate of administration of radiopharmaceuticals does not necessarily result in a corresponding increase in population dose. Improved instrumentation and procedures for function studies and tissue scanning and the availability of new tracer agents have materially lowered the patient dose in many procedures. Wellman, Kereiakes, and Branson (*17*) reported on the thyroid doses in children (in rads per microcurie administered) receiving iodine-131, iodine-125, and iodine-123 as sodium iodide. Between iodine-131 and pure iodine-123, the reduction in dose was nearly two orders of magnitude. The largest doses were received by the youngest children for each isotope. Similarly, McAfee (*18*) observed that the doses to the kidneys and the liver were reduced by about an order of magnitude when mercury-197 was used instead of mercury-203 as chloromedrin in equivalent microcurie quantities.

Whole body doses have been calculated (*17*) from administrations of chromium-51 (as sodium chromate) and of iron-59 (as ferrous citrate). Whole body and organ doses were also reported for other radiopharmaceuticals: mercury-197 (chloromedrin), mercury-197 and -203 (neohydrin), selenium-57 (selenomethionine), calcium-47 (calcium chloride), strontium-85 (strontium nitrate), technetium-99m (Tc-Fe complex, Tc sulfur colloid, and TcO_4). These studies were all done in children.

Mean dose rate to the whole body and to various tissues and organs were estimated by Cloutier and Watson (*19*) for phosphorus-32, chromium-51, iron-59, technetium-99m, and iodine-131. These investigators also provided data which distinguished between mean dose rates from nonpenetrating radiation and those from gamma radiation. This distinction has special relevance in nuclear medicine, particularly in the case of radionuclides that emit weak beta particles and exhibit "hot spots" at the cellular or subcellular level (*18–20*). Similar considerations apply to radionuclides that decay by electron capture (*18*) as in the case of iodine-125. Average doses to various hard and soft components of bone and to bone marrow have been calculated by Spiers (*21*) following admininstration of the beta-emitting radionuclides, carbon-14, calcium-45, sodium-22, fluorine-18, phosphorus-32, and strontium-yttrium-90.

Some comparisons have been made between doses from x rays and radioisotopes in various diagnostic procedures (*22*). It is to be expected that the dose distributional patterns will differ widely for the two types of procedure. The region of diagnostic interest will, of course, be the prime factor in determining the relative dose to tissues situated in the region. Thus, in examinations directed to the abdominal and pelvic areas, x radiation will deliver larger doses to the gonads than will most radiopharmaceutical procedures. The reverse is true of examinations involving the head and chest. In general, skeletal examinations with the use of bone-seeking radionuclides (fluorine-18, strontium-85) will result in higher bone doses than would be the case with x-ray examinations.

The genetically significant dose (GSD) to the population from radiopharmaceuticals is still very small compared to that from x-ray examinations. Trott et al. (*22*) estimated that in the United Kingdom diagnostic radioisotopes "probably still contribute less than 1 percent to the total genetic dose due to medical use of ionizing radiation." Early estimates (*1*), based principally on administrations of iodine-131 and phosphorus-32 before 1960, gave GSD values ranging from 0.01 to 0.03 mrem/a for diagnostic radioisotopes.

A recent study of a sample of hospital inpatients receiving in vivo radioisotope tests provided some comparisons of doses to the whole body, gonads, and various organs from diagnostic radionuclides and x rays (*23*). The authors found that in this sampling, the average gonad dose for these patients from radioisotopes increased from 0.06 rad in 1964 to 0.14 rad in 1968, while the average total body dose increased from 0.1 rad to 0.16 rad. The average gonadal exposure from x-ray examinations of these same individuals remained unchanged at about 1.2 rad. During this period, the total number of radioisotope procedures increased by 106 percent, while that for x-ray procedures increased by 48 percent. The gonad dose data obtained in this study should not be considered in terms of genetic effects since most of the patients were 45 years of age or older. It is of interest, however, that the study confirms other findings of an increasing trend in the use of radioisotopes and their potential contributions to population dose.

Occupational exposure

Individuals may be exposed to radiation as a consequence of their occupation, either because they are directly engaged in radiation work (medical practices, industry, research, etc.) or because their occupational activities take place where exposure to radioactivity is significant. The exposures can be external or internal, the latter arising through inhalation of radioactive gases and dusts and through the ingestion of radioactively contaminated material. Data available on the number of subjects occupationally exposed shows a maximum of 1.8 individuals per thousand of population. Other data available from UNSCEAR reports on the occupational genetically significant dose indicate that it does not exceed 0.5 mrem/a as averaged over the whole world (*1*). Doses to individuals of particular occupations, however, may range much higher. For example, the skeletal and gonadal doses from polonium-210 to uranium miners are as high as 6.6 rem/a and 150 mrem/a, respectively (*24*).

Exposure from consumer devices

Many objects in common use contain radioactive material or emit radiation. Luminous watch and clock dials are the most common, but a host of luminous devices is to be found on the market in increasing numbers. A number of other objects also incorporate radioactivity; these include static charge eliminators, smoke detectors, electronic tubes, and ceramic glazes containing uranium. X rays are emitted from television sets and from other electronic devices. The contributions to the genetically significant dose from each of these sources are small.

The use of these miscellaneous sources is likely to contribute about 2 mrem/a (*3*) mainly from the use of luminous clocks and watches, and television. However, with the increasing use of miscellaneous sources of radiation, none of which individually contributes an appreciable dose, the total genetically significant dose may be expected to increase slightly.

An estimate of exposure from man-made sources other than evironmental contamination was presented in a Federal Radiation Council report (*3*). The estimate was based on reports published before 1960 and probably would not hold for present conditions.

A more recent estimate of relative exposures was made by Morgan (*25*). He estimated that 94 percent of the total GSD from man-made sources of ionizing radiation was due to medical exposure, and 90 percent of this was from diagnostic x rays. Of the balance of 6 percent, 4 to 5 percent was attributed to weapons fallout and 1 to 2 percent to all other sources (occupational exposure, luminous watch dials, color television receivers, radioisotope applications, etc.).

Environmental contamination

Nuclear weapons fallout exposure

Debris from atmospheric nuclear tests remains the most important man-made radioactive contaminant of the environment. Many radionuclides of various half-lives are present in fallout. Those which have received the most attention are:

Radionuclide	Half-life
Zirconium-95	65 days

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Niobium-95	35 days
Cesium-137	30 years
Strontium-90	28 years
Carbon-14	5,730 years
Iodine-131	8 days

Some of these contribute to both internal and external exposure; others to internal exposure only. The main contributions to external irradiation from fallout come from the first three abovementioned nuclides, all of which emit gamma rays. Because of the great difference between their half-lives, the respective contribution from stratospheric fallout from ^{95}Zr−Nb and ^{137}Cs to the total tissue dose depends on the stratospheric residence time. Because of the relatively short half-life of zirconium and niobium, much of their decay may occur before deposition whereas cesium-137, with a half-life of 30 years, decays mainly after deposition on the ground and consequently contributes a substantial tissue dose. Strontium-90, cesium-137, iodine-131, and carbon-14 are the main contributors to internal exposure. The amounts, the relative proportion of different nuclides, and subsequent exposures vary with time. Since fallout deposition shows wide geographical variations, estimating the dose received by the world population as a whole is particularly complex. The dose rate in a given year must be seen in context with all the separate and varying yearly dose rates from all radionuclides in order to obtain an estimate of the total dose. It is, therefore, more appropriate to compute the total integrated dose contribution that is being and will be delivered from past explosions. This contributon is called the dose commitment.

The dose commitment from nuclear tests carried out before 1968 has been estimated by the UNSCEAR (*26*). The dose commitments to the gonads from external radiation sources (short-lived radionuclides and cesium-137) ranged from 72 mrad in the north temperate zone to 16 mrad in the south temperate zone. The gonadal dose commitment from internal sources (cesium-137 and carbon-14) were 34 and 17 mrad, respectively, for the two zones. For dose commitments to the cells lining the bone surfaces, the contribution of strontium-90 (130 mrad in the north temperate zone and 28 in the south temperate zone) was added. In the case of dose commitments to the bone marrow, the respective contributions of strontium-90 were 64 and 14 mrad. The contribution of strontium-89 was less than 1 mrad in all cases.

In presenting these data, the UNSCEAR stated:

> "Most of the amount of long-lived nuclides injected into the stratosphere by earlier tests had been deposited by the middle of 1967. However, substantial fractions of the total doses to which the population is committed remain to be received from present body burdens and from the deposit in soil which will continue to be transferred to foodstuffs. This is particularly true in the case of strontium-90 which remains available for absorption by plant roots and is retained for long periods in the human skeleton. Present estimates indicate that roughly one-eighth of the total expected population dose due to strontium-90 had been delivered by the end of 1967, compared with between two-thirds and three-quarters of that due to the total amount of cesium-137 available for deposition in the body. On the other hand, only a small fraction of the expected population dose due to carbon-14, the radioactive half-life of which is much longer, has so far been delivered, and somewhat less than one tenth of it will have been delivered by the year 2000. By contrast, more than half of the contribution to the dose commitment from external sources has already been delivered.
>
> For the purpose of estimating dose comments, UNSCEAR has used more extensively than heretofore actually measured levels of long-lived radionuclides in human tissues. This is particularly so in the case of strontium-90, which poses special problems because of its long retention in soil and bone and because of its complex metabolism in human tissues. By making use of measured levels in tissues, UNSCEAR has been able to avoid some of the assumptions previously needed. Though a large number of other assumptions are still necessary and are common to all methods of calculation, the method now used will enable UNSCEAR to use more efficiently the results of future measurements to verify and, if necessary, modify those assumptions in the future."

Operating nuclear facilities

Based on data compiled by the Division of Environmental Radiation, Bureau of Radiological Health (now the Radiation Office, EPA), and presented in table 5, it appears that nuclear power stations with one exception were operating today at approximately 1 percent of their annual average noble gas discharge limits as provided in their technical specifications. Data from environmental samples obtained in the boiling water reactor study at the Dresden Nuclear Power Plant site show that radioactivity was not detectable in the water or food pathways; thus, measurable population exposure is restricted to external exposure from the noble gas plume where radiation was detectable. Exposures via this mechanism were very difficult to measure with certainty because gaseous releases from the plant resulted in environmental levels which were only a small fraction of background levels and therefore difficult to distinguish from background. Initial measurements of external dose rates showed that the offsite external dose rates vary from 5 to 15 mrem/a depending upon location, time, and technique of measurement. The offsite external dose rate of 5 to 15 mrem/a measured at the 200 MWe Dresden Nuclear Power Station can be used to obtain a conservative estimate of external exposures resulting from such power plants operating at higher power levels if the noble gas dose rate is assumed to be proportional to power level. This linear extrapolation of dose rate with power level is conservative because fuel performance will improve with advances in reactor technology, thus lowering the core fission product inventory escaping via leaking fuel elements. However, multiple plant siting may increase the external exposure rate in the multiple plant site environs and tend to make the linear extrapolation based on power level less conservative. The plume exposure from a pressurized water reactor would be expected to be much less due to its lower emission of noble gases.

Multiple reactor sites present problems relative to the establishment of radioactive effluent discharge limits in addition to those caused by the long-term buildup of radioactivity in the aquatic environment including the reconcentration phenomenon in biological media. These discharge limits will have to be developed carefully, utilizing the best available information and the many environmental aspects that influence the possible population exposure, to assure that the total dose to the population from multiple reactor sources is minimized. The potential impact of these exposures can be seen from table 6, which shows the populations within 10 miles and 50 miles of a number of nuclear power plants presently operating or under construction.

Peaceful uses of nuclear explosives

Potential population exposures from the peaceful applications of nuclear explosives—the Plowshare program—relate basically to three types of releases of radioactivity:

1. Releases from cratering shots,
2. Releases from ventings of underground shots,
3. Radioactivity in the flaring and, presumably, in

Table 5. Annual gaseous radioactive waste discharges expressed as percent of limit[a] (noble and activation gases)

Reactor	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
PWRs[b]										
Shippingport	0.035	0.073	0.26	0.03	0.87	0.006	0.08	0.075	0.005	0.0025
Yankee			.000014	.32	.11	.014	.025	.035	.036	.008
Indian Point-1					4.5×10^{-7}	.00083	.0020	.0022	.0015	.0037
San Onofre									.0024	.00085
Connecticut Yankee									.00003	.0039
BWRs[b]										
Dresden-1			.158	1.29	.32	2.37	2.77	3.34	.87	1.09
Big Rock Point						.0025	.43	2.27	.85	.74
Humboldt Bay					.045	.38	12.5	17.8	56.7	54.0
HTGR[b]										
Peach Bottom-1								6.67×10^{-6}	.04	.067

[a] Table was taken from reference 27. This reference should be consulted for the quantities discharged and the discharge limits.
[b] PWR–pressurized water reactor; BWR–boiling-water reactor; and HTGR–high temperature gas-cooled reactor.

Table 6. Population density around nuclear power plants

Reactor	Location	Type[a]	Power level (MWt)[b]	Year operational	Year of population estimate	Population <10 miles	Population <50 miles
Browns Ferry Units 1, 2, & 3	Decatur Ala.	BWR	[illegible]	1972, 72, 73	1960	22,040	523,940
Calvert Cliffs Units 1 & 2	Lusby, Md.	PWR	[illegible]	1973, 74	1965	13,180	2,371,880
Connecticut Yankee	Haddam Neck, Conn.	PWR	1,473	1967	1960	49,640	(c)
Donald C. Cook Units 1 & 2	Bridgman, Mich.	PWR	3,250	1972, 73	1965	45,959	1,066,849
Diablo Canyon	Diablo Canyon, Calif.	PWR	3,250	1973, 74	1960	[d]1,570 [e]3,500	151,490
Dresden Unit 1	Morris, Ill.	BWR	700	1960, 70, 70	1950	21,000	(c)
Ft. Saint Vrain	Platteville, Colo.	HTGR	841.7	1972	1960	8,420	(c)
Indian Point Unit 1	Indian Point, N.Y.	PWR	615.0	1963	1960	155,420	(c)
Millstone Point Unit 1	Waterford, Conn.	BWR	2,010	1970	1965	[d]95,864 [e]118,000	2,270,042
Monticello	Monticello, Minn.	BWR	1,400	1970	1960	9,712	(c)
Oconee Units 1, 2, & 3	Seneca, S.C.	PWR	2,452	1971, 72, 73	1965	36,334	992,500
Oyster Creek Unit 1	Toms River, N.J.	BWR	1,600	1969	1960	37,456	(c)
Palisades	South Haven, Mich.	PWR	2,121	1970	1960	25,743	870,515
Prairie Island Units 1 & 2	Red Wing, Minn.	PWR	1,650	1972, 74	1960	15,292	(c)
Quad Cities Units 1 & 2	Cordova, Ill.	BWR	2,255	1971, 71	1966	39,488	(c)
Rancho Seco	Clay Station, Calif.	PWR	2,452	1972	1965	4,060	1,348,548
Russellville	Lowdon, Ark.	PWR	2,452	1973	1967	22,993	155,475
Sequoyah Units 1 & 2	Daisy, Tenn.	PWR	3,423	1974, 74	1960	24,920	604,120
					1960	54,325	757,545
Surry Units 1 & 2	Gravel Neck, Va.	PWR	2,441	1971, 71	1960	309,460	919,317
Turkey Point Units 3 & 4	Homestead, Fla.	PWR	2,007	1971, 72	1966	42,397	1,378,938
Zion Units 1 & 2	Zion, Ill.	PWR	3,391	1971, 73	1960	188,800	5,664,515
Average population <10 miles (permanent population using 1960 Sequoyah population)						59,991	
Average population <50 miles (using 1960 Sequoyah population)							1,386,000

[a] BWR–boiling water reactor; PWR–pressurized water reactor; HTGR–high temperature gas-cooled reactor.
[b] Refers to first reactor at site where more than one reactor exists or is being built.
[c] Not available.
[d] Permanent.
[e] Summer.

the ultimate distribution of natural gas from a cavity formed by a nuclear detonation. Such distribution has not taken place to date.

From December 1961 through September 1969, 24 Plowshare experiments were reported. Of these, six were primarily cratering experiments (one, a row charge cratering experiment with five simultaneous detonations), and two were gas stimulation experiments.

When releases from ventings and cratering shots occurred, the findings of radioactivity in milk were shown to be regional and spotty even within the regions affected (*28, 29*). Monitoring of such releases is rendered difficult when it is considered that "calculations also indicate that milk levels of 1,000 to 5,000 [pCi iodine-131 per] liter could occur when external gamma levels due to fallout are too low to distinguish from natural background by routine field survey methods" (*30*). In view of the localized, sporadic nature of these exposures, it is inappropriate to attempt to calculate organ and genetically significant doses to the U.S. population from such occurrences.

Special considerations of environmental radionuclides

A number of potential sources of exposure requiring special investigation, both from a dose commitment and biological effects standpoint, are: tritium, krypton-85, discharges of various other noble gases from nuclear facilities, doses resulting from occupancy of dwellings constructed on tailings from uranium mill operations, and doses to local population groups from intake of highly contaminated foods or water.

Tritium[2]

Tritium occurs naturally in the environment as a product of cosmic-ray bombardment of nitrogen in the upper atmosphere (*31*). It is also produced as a ternary fission product, as a product of thermonuclear reactions, by various types of reactions in nuclear reactors and in tritium production facili-

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[2] We are indebted to the report of D. G. Jacobs, of Oak Ridge National Laboratory (*43*) for much of the material in this section.

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ties. Of chief concern from the standpoint of population exposure are the releases from past thermonuclear atmospheric tests and from operations of the nuclear power industry, particularly in the processing of nuclear fuels.

An early report on the tritium content of natural surface waters indicated that there was about one tritium atom for every 10^{18} atoms of hydrogen (*32*). Kaufman and Libby (*33*) estimated an inventory of about 1,800 g (17 megacuries) on the earth, with 11 g (0.1 megacuries) in the atmosphere, 13 g (0.12 megacuries) in groundwater, and the remainder in the sea. These estimates of natural tritium production and inventory may have been low, (*cf.* "Population doses and projections," below).

Contributions from nuclear explosions

Thermonuclear detonations are the principal considerations in this regard. Leipunsky (*34*) estimated that the explosion of a 10-megaton-equivalent pure hydrogen bomb (deuterium-tritium reaction) would result in a residue of 7 kg of tritium (about 66 megacuries). In addition to this direct yield from fusion reaction, the neutron irradiation of nitrogen may yield an additional 1.5 kg of tritium (*35*). (The neutron release from an equivalent fission explosion would yield about 0.2 kg of tritium.) In addition, interactions of neutrons with the materials of the device itself could lead to increased tritium releases ranging as high as 5 kg of tritium per megaton equivalent from the explosion of a fusion device (*36*).

The partition of tritium in the environment from fusion detonations will vary with the placement of the shot. A fraction of the fission-produced tritium migrates through the fuel cladding and reaches the primary coolant. In pressurized water reactors soluble boron and lithium are present in the primary coolant to regulate neutron flux. Neutron bombardment of isotopes, lithium-6 and boron-10, produces tritium. By 1960, the concentration of tritium in stratospheric water had risen by about five orders of magnitude over pretest levels.

Tritium releases from nuclear reactors

In light-water reactors, tritium is produced in the course of fission of the reactor fuel and by neutron bombardment of certain elements. Some tritium is produced by fast neutrons acting on boron-10 in the control rods, or in borate solutions used in some control systems, or on nitrogen-14 present in the residual air. Most of the tritium is produced by thermal neutron irradiation of deuterium, helium-3, or lithium-6 in the reactor coolant. The rates of release into the environment depend on the type and the operating conditions of the reactor and are normally low. Much of the fission-product tritium is retained within the cladding of the fuel elements and in the primary coolant system.

In heavy-water reactors, where the heavy water can be used as a moderator, reflector, and a coolant, tritium is formed primarily by neturon bombardment of deuterium and relatively little is lost from the heavy-water system. Some estimates of tritium releases from heavy-water reactors have been published. At Chalk River in Canada, some 3 curies of tritiated water vapor have been released daily from the stack (*37*). Releases to surface waters at the Savannah River Plant, primarily from the heavy-water reactors, have resulted in concentrations of tritium in the river ranging around 10 nCi/liter, which is less than 1 percent of the maximum permissible concentration (*38*). It has been suggested that tritium activity resulting from the operation of a large heavy-water power plant will be as important to radiological health as all other radionuclides combined because of its vapor pressure (*39*).

Tritium releases from fuel-reprocessing plants

Spent fuel from nuclear reactors is processed commercially at only one location in the United States at present. This facility, Nuclear Fuel Services, Inc. (NFS), is located in Cattaraugus County, N.Y. In the preoperational statement (*40*), it was estimated that about 200 curies of tritium would be released per day during reprocessing operations. Of this, 25 percent would be released through the stack, 65 percent via discharge into a waterway (Buttermilk Creek), and the remaining 10 percent would be held as waste storage. These estimated proportions are not too different from values reported for the Hanford Plant (*41*).

Monitoring of the atmosphere, liquid waste discharges and water in the NFS operational area showed the following: (a) the concentration of offsite tritiated moisture in the atmosphere tended to be highest northwest of the plant (*42*) reaching levels as high as 14 nCi/liter of atmospheric water; (b) the general practice of releasing liquid wastes in proportion to the flow in Cattaraugus Creek (which receives the flow from Buttermilk Creek) provided a degree of dilution such that the concentration averaged little more than 10 times the average concentration in the statewide surface water systems (*43*). Releases from fuel reprocessing plants result in relatively high local concentrations of tritium (and krypton-85, which will be discussed below). As the nuclear power industry expands and the number of fuel reprocessing plants increases, tritium is expected to become a substantial factor in consideration of population exposure.

Population doses and projections

Projections of fission-product tritium from nuclear power plants in the free world have been made for the period 1965 to 2000 (*44*). Based on predictions of power production, assumptions of load factors and thermal efficiency, and data derived from light-water-cooled reactor operations, it was estimated that by the year 2000 a total of 96 megacuries of tritium will have accumulated. If the production rate predicted for the year 2000 (15 megacuries per year) is maintained thereafter, a steady-state level of 260 megacuries of accumulated tritium will result.

Jacobs made an interesting observation on the probable value of natural tritium production, which was taken to range from 0.5 to 1.0 atom/cm^2-sec. This value would yield an annual production of about 4 to 8 megacuries and result in a steady-state inventory of 70 to 140 megacuries. In his projection of fission-product tritium produced in reactors, the rate of tritium produced would begin to exceed that of natural tritium about a decade before the turn of the century (*44*).

In a power economy in which heavy-water-moderated reactors assume a substantial role, or if thermonuclear reactors come into the picture, the rate of tritium production will be enhanced.

Local exposure to tritium can amount to an appreciable fraction of the Radiation Protection Guides. It has been calculated that in the reprocessing of fuel for 100,000 MW (thermal) production, the rate of release of tritium would be 14 mCi/s, and the atmospheric concentration at the plant site would be about 6 nCi/m^3. Assuming the stack release to be in the form of HTO, the average annual occupational dose to the whole body, through inhalation and skin absorption, would be 4 mrem/a. This was calculated on the basis of a 40-hour exposure per week, using a quality factor of 1.7. Under these conditions, a steady-state, ground-level air concentration of 1.1 nCi/m^3 would be reached about 1 mile away. The dose rate to the population in this area for constant (168-hour week) exposure would be somewhere between 2 and 3 mrem/a (*44*).

Additionally, the tritium sampling network of the Public Health Service has shown tritium values of 2 to 20 nCi/liter in surface waters of the United States (*45*, *46*). Assuming the same specific activity in the body, the estimated whole body doses in these areas would range from 0.33 to 3.3 mrem/a.

Dilution of the tritium, particularly that released to the atmosphere, will dissipate the exposure to the general population. Estimates of dose to the world population from tritium released in the course of projected United States nuclear power production in the year 2000 have ranged as low as 2 μrem/a (*47*).

Krypton-85 and other radioactive noble gases

Radioactive noble gases are fission products and are produced in the nuclear fuel system of reactors. Estimates of the yield of noble gas fission products from uranium-235 are presented in table 7 (*48*). In addition, certain types of reactors also produce radioargon, an activation product. For example,

Table 7. Noble gas fission products from uranium-235 (having yield >0.01 percent and half-life >1 min)

Isotope	Half-life	Yield (percent)
Krypton-83m	114 minutes	0.54
Krypton-85m	4.4 hours	1.10
Krypton-85	10.7 years	.29
Krypton-87	76 minutes	2.49
Krypton-88	2.8 hours	3.57
Krypton-89	3.2 minutes	4.59
Xenon-131m	12 days	.02
Xenon-133m	2.3 days	.17
Xenon-133	5.3 days	6.62
Xenon-135m	15.3 minutes	1.83
Xenon-135	9.1 hours	6.30
Xenon-137	3.9 minutes	6.00
Xenon-138	17 minutes	5.49

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the Brookhaven Graphite Research Reactor discharged over 20 kCi/day of argon-41 (110-minute half-life) while operating at 20MWt(*49*). During 1964, radiation levels at offsite monitoring stations averaged 0.06 mR/week from this source.

It is noteworthy that only one of the noble gas fission products, krypton-85, has a half-life measurable in years. It, therefore, presents the greatest potential for buildup in the environment.

An environmental surveillance study at a boiling water reactor (Dresden Nuclear Power Station of the Commonwealth Edison Company) has been reported in detail (*50*). This plant had been operating at a rated power of 700 MW (thermal) and 210 MW (electric) since 1962. The prominent noble gas radionuclides in stack effluent, as measured by gamma spectral analysis of delay-line samples, were krypton-85m,-87, and-88, and xenon-133,-135, and-138. Xenon-135 was the only radioactive noble gas among the major predicted constituents that could not be quantified. One day after release, only krypton-88 and xenons 133m, 133, and 135 were detected by gamma-ray spectrometry. After one month, only xenon-133 and krypton-85 were identified.

It is important to note that krypton-85 is predominantly a beta particle emitter. Its decay yields 99.565 percent of 0.675 MeV (maximum energy) beta radiation and 0.435 percent low energy beta radiation and gamma radiation of 0.514 MeV. The gamma photons occur in only 0.41 percent of the krypton-85 disintegrations. These characteristics in addition to the chemical inertness and low solubility of the gas, form the bases for determining doses to exposed populations.

Most of the krypton-85 produced in nuclear power reactors is released during the reprocessing of spent fuel. At any given time, the inventory of krypton-85 resulting from nuclear power plant operations will consist of: (a) the krypton-85 retained in the fuel elements, (b) that released from the reactor stacks, and (c) that stored in or released from the fuel reprocessing operations. The proportions will vary according to the type of reactor and the fuel exposure in the reactor.

Estimates of projected krypton-85 production have been prepared by a number of analysts (*51–53*). Their findings are shown in table 8.

Table 8. Cumulative krypton-85 production estimates

Source	Quantity (megacuries)				
	1970	1980	1990	2000	2060
Cowser et al. (free world) (*51*)	13	210	1,100	3,150	
Coleman and Liberace (world) (*52*)[a]	15.4	200	1,000	4,000	120,000
Mountain et al. (U.S. only) (*53*)	11	220	970	3,100	

[a] Assumes a changing mixture of reactor types, including thermal converters and fast breeders. Values calculated from concentration projections.

The premises and assumptions for the different calculations vary among the three projections, but the projections do not differ by anything like an order of magnitude.

Dose estimates based on the above projections, compiled by Fowler and Voit (*54*), are shown in table 9.

Table 9. Comparison of the estimated annual average skin surface dose from krypton-85

Source	Estimated annual average skin surface dose (mrem/a)				
	1970	1980	1990	2000	2060
Reference (*51*) (worldwide)	0.008	0.12	0.63	1.8	
Reference (*52*) (world)	.006	.08	.41	1.6	50 I
Reference (*53*) (U.S. only)[a]	.07	1.4	6.3	20	

[a] Basis used was dilution only over the tropospheric volume of the United States (2.69 × 10^{22} cm^3).

These estimated annual dose calculations relative to the beta radiation are applicable to the skin surface of the body. Attenuation of this beta radiation by the skin tissue occurs at a rate that yields a negligible whole body dose. Calculations by Fowler and Voit (*54*) and by Hendrickson (55), which show reasonable agreement, indicate dose rates at various tissue depths as listed in table 10.

Table 10. Calculated dose rates at various tissue depths

Depth in tissue (mm)	Percent of dose[a]
0 (surface)	100
.07 (shallowest layer of live skin)	52
.1	40
.2	20
.3	10
1.0	.08
2.0	.00008

[a] From krypton-85 beta radiation (maximum energy, 0.675 MeV).

Hendrickson (*55*) has also presented calculations of tissue doses from combined beta and gamma plus x radiation (bremsstrahlung). The total average energy of these penetrating rays was calculated to be 2.83 keV/disintegration (2.23 keV β-γ plus 0.6 keV bremsstrahlung). Based on a krypton-85 concentration in air that would produce a dose of 50 mrem/a to the skin surface (Coleman and Liberace projections for the year 2060) (*52*), the doses to tissues would be as shown in table 11.

Table 11. Tissue doses from immersion in air containing krypton-85 concentration of 20 pCi/g of air[a]

Tissue	Tissue depth (mm)	Beta radiation (mrem/a)	X and gamma radiation (mrem/a)
Whole body	[b]50	nil	0.7
Gonads	10	nil	.7
Gonads	2	4×10^{-6}	.7
Skin surface	0	50	.7
Skin[c]	.07	30	.7
Lens of eye	2	4×10^{-6}	.7
Lung[d]	0	0.5	.7

[a] Adapted from Hendrickson (*55*).
[b] Average.
[c] Shallowest layer of live skin.
[d] Internal exposure to surface tissue of lung.

Calculations of dose from krypton-85 dissolved in body fluids and tissues are in progress and will be published in the near future.

Thus, krypton-85 remains as a potential future source of environmental contamination requiring evaluation by those concerned with the balancing of risks and benefits of nuclear energy.

Various methods for removal of krypton-85 have been proposed. These have been reviewed by Fowler and Voit (*54*) and include solid absorption, cryogenic distillation, electrostatic diffusion, and permselective membrane separation coupled with underground storage of the separated krypton-85.

Other sources of exposure

To provide a basis for protecting the health of the public from undue exposure to ionizing radiation, it is necessary to establish a system which will provide a continuing evaluation of population exposure. This system must be responsive to all sources of radiation exposure and provide the technological data upon which decisions can be made with respect to the relative impact of each source in relation to the total exposure. Potential sources of exposure requiring critical investigation include, in addition to the factors discussed above:

1. Dose associated with peaceful uses of nuclear explosives (Plowshare Program);
2. Dose resulting from residence in an area with an unusually high radiation background; and
3. Doses to population groups that have special dietary intakes or other special exposure situations.

Limited amounts of data are available with respect to the production of radioactivity as a result of Plowshare experiments. Environmental survey findings have been reported following a cratering experiment (Project Schooner, a 35-kiloton fission explosion at the Nevada Test Site on December 8, 1968) (*56*). Gross beta radioactivity increased in a number of northwestern States, and fresh fission products were detected over a wide range of States. Only one Pasteurized Milk Network (PMN) station reported a detectable concentration of iodine-131, and two reported barium-140. The concentrations were close to their minimum detectable levels, and it was concluded that these did not represent a public health hazard.

Project Gasbuggy, a contained, natural gas-stimulation experiment, was conducted on December 10, 1967. Offsite surveillance revealed no radioactivity above preshot levels in air, milk, and water, and no intrusion of radionuclides into producing water wells in the vicinity (*57*). The gas produced has not been released into distribution pipelines and therefore presents no population hazard except possibly for the minimal exposure resulting from flaring of the gas.

A Federal program of monitoring dwellings constructed on uranium mill tailings was instituted during late 1970. Findings were not available as of the date of preparation of this report.

Dose estimates for populations with special dietary intakes will become increasingly important as nuclear installations proliferate. Honstead (*58*) has described studies indicating that radionuclide burdens in children in the vicinity of the Hanford Project were increased where diet sources were

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related to the Columbia River. The survey procedure described would provide dose estimates "to a typical resident and to a special population group having diet habits that maximize exposure."

Dose commitment concept

This refers to the procedure of attributing to a particular environmental contamination all the subsequent exposure that will result from the contamination. It was defined by the UNSCEAR (*2*) as follows: "... the dose commitment to a given tissue is ... the integral over infinite time of the average dose rates delivered to the world's population as a result of a specific practice; e.g., a given series of nuclear explosions. The actual exposures may occur over many years after the explosions have taken place and may be received by individuals not yet born at the time of the explosions..."

Utilizing this procedure, we can then consider such things as the dose commitment from all nuclear weapons testing prior to 1968. This implies that these nuclear weapons have contaminated the environment in an irreversible manner which has committed the population to this dose. Although the UNSCEAR definition relates to an infinite time integral, it should be realized that the per individual addition of dose is considered only for a life-time period (50 to 70 years).

This concept is useful in assessing the health impact of any given quantity of radionuclides introduced as the result of contaminating events. It could apply to a single intake episode (e.g., a dose of a thorium compound or other diagnostic radiopharmaceutical) or to describe natural radiation exposure, considering each person's exposure to start at the time of conception. Although the dose commitment concept has mainly been applied to the case of exposure of the world population to radiation from nuclear tests, the concept is, in principle, applicable to other cases. For estimating the value of the dose commitment, however, it may be necessary to take into account various specific properties affecting the distribution of dose among members of the population. The dose commitment is then obtained as the average of the dose commitments to the relevant subpopulations, appropriately weighted by subpopulation size.

Calculating the dose commitment then becomes mainly a problem of predicting changes in the amounts and distribution in the body of the relevant radionuclides. In practice, this may involve not only considerations of the metabolism of the nuclides in various organs and tissues, but also considerations of environmental vectors that contribute to both internal and external radiation dose.

The internal radiation dose commitment to the whole body or to a specific organ or tissue of an individual in a population group is the product of (1) the factor for converting activity intake of the specific radionuclide to dose, (2) the weight or volume intake of the media containing the radionuclide per individual per unit time, and (3) the concentration of the radionuclide in the media.

A summary of dose commitments to the gonads, cells lining bone surfaces, and bone marrow as result of nuclear explosions was presented in an UNSCEAR report (*2*). The period covered was 1954 to 1965, and the dose commitments listed dealt with external, short-lived radiation, carbon-14, cesium-137, and strontium-89 and -90. An evaluation of internal radiation exposure, based on dose commitments from radionuclides in milk, food, and air was performed by Shleien (*59*), using data from existing surveillance networks. This report provided dose commitments to critical organs (in mrem for 50 years) (1) for maximum doses to infants accrued in any one year, and for (2) adults from intakes occurring during various periods from 1961 to 1968 in the northeastern United States. The largest dose commitments in the adult group were the dose to bone from strontium-90 dietary intake and the dose to the respiratory lymph nodes from plutonium-239 and plutonium-238 inhalation during the 1965–1968 period. The plutonium resulted from two principal sources; atmospheric inventory from nuclear weapons testing, and the re-entry and burnup of an orbiting device carrying 17,000 curies of plutonium-238 in April 1964.

These dosimetric calculations provide information required for evaluation of present surveillance operations and guidance for future surveillance requirements. The procedure is potentially applicable to monitoring surveys around nuclear facilities and evaluation of possible releases from peaceful uses of nuclear energy (*59*). In some of these cases, the concept should be even eas-

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ier to apply as there would be no need to consider injection and long-term holdup in the upper atmosphere as well as the fact that the population at risk would be more limited and better defined.

In view of widespread concern with the potential hazards of ionizing radiation in the environment, there is need for continuing review and evaluation of relevant information in order to reassess existing radiation protection standards. The evaluation should provide estimates of risks associated with low-level environmental radiation as a basis for reviewing the adequacy of current guidelines as applied to projected radiation levels. Based on projected exposures, the need for possible dose apportionment among the more important sources of radiation exposure should be considered. The International Commission on Radiological Protection (*60*) propounded a principle relevant to the subject in the following statement:

> "The suggested maximum genetic dose of 5 rems in addition to the dose from medical procedures and natural background must not be used up by one single type of exposure."

It is of interest, therefore, to examine in perspective those sources of exposure that present important areas of current and future public health concern.

Dose rates and dose commitments from natural background radiation remain constant worldwide. Surveillance of various geographic regions may have some value for purposes of studies of biological effects and for site selection for nuclear power operations. Assuming that there will be no substantial resumption of atmospheric nuclear detonations, the trend of dose commitment to the population from atmospheric fallout will decline. Table 12 compares the 50-year dose commitments from fallout produced by weapons tests conducted before 1968 with that from average natural background.

In addition, consideration should be given to other specific areas of dose commitment, such as: radioiodine dosage to the thyroid gland; radiostrontium, radium, radiobarium, and plutonium dosage to mineral bone; radioiron to blood-forming cells and spleen; and of various radionuclides to such tissues and organs of reference as the gastrointestinal tract, liver, lung, kidney, pancreas, and muscle. Guidance on the relative significance of exposure to specific radionuclides may be obtained by reference to National Bureau of Standards Handbook 69 (*61*).

Table 12. Fifty-year dose commitment (mrem) from fallout (weapons tests before 1968)[a]

Source	Whole body	Gonads	Cells lining bone surfaces	Bone marrow
Internal radiation from fallout:				
Cesium-137	21	21	21	21
Carbon-14	13	13	16	13
Strontium-90	....	....	130	64
Strontium-89	....	....	<1	<1
External (total) radiation from fallout:	50-100			
Short-lived	....	36	36	36
Cesium-137	....	36	36	36
Natural background radiation:				
External	4,000	4,000	4,000	4,000
Internal	1,050	950	1,200	1,000

[a] Adapted from reference (*8*).

A special case is the calculation of a genetically significant dose which, particularly for medical and occupational exposure includes in the "genetic pool" individuals not directly exposed in the particular procedure.

Trends toward increasing population dose commitments are attributable to two main areas of application of ionizing radiation: medical diagnostic x radiation and uses of radioisotopes, and the growth of nuclear power operations.

Medical (includes dental) uses of radiation for diagnosis

X rays

The population dose from x rays in the United States for 1964 has been evaluated in terms of estimates of gonad and genetically significant dose to the population (*7*). As indicated earlier, this genetic dose was estimated to be 55 millirads per person per year, 96 percent of which was contributed by radiography, about 4 percent from fluoroscopy, and a minute amount from photofluorography. Based on various assumptions with respect to increased rates of x-ray examinations and limited projected improvements in practice, Kessner and Brown (*62*) projected genetically significant doses ranging from 150 to 365 millirads per year to the population by 1990.

Administration of radionuclides

Dose calculations for systemic radionuclide administrations require a comprehensive assessment of dose to the whole body as well as to various organs of interest. Of particular interest for determining population (e.g., genetically significant) dose is the dose to the gonads. This is usually assumed to be approximately equal to the mean whole body dose (*22*). It has been estimated that for the near future, the annual growth rate of nuclear medicine would be as high as 15 percent (*63*). If we assume the genetically significant dose from nuclear medicine procedures to be about 0.5 millirads for the year 1970, a likely assumption if we accept the estimate of Trott (*22*), then the projected GSD for 1980 would exceed 2 millirads. To this should be added the doses to personnel engaged in the preparation, administration, and other handling procedures involved.

Nuclear power generating sources and associated operations

The population dose relatable to nuclear power operations would include the total exposure from mining and milling operations, transportation, processing, reactor applications, fuel reprocessing, waste storage and disposal, and are affected by dilution factors from releases into the environment as well as concentration factors in media that enter the food chain.

Radiation doses from all sources to which large or substantial portions of populations are exposed are regularly reviewed by advisory groups. In 1962, the National Advisory Committee on Radiation identified a number of public health problems concerned with radioactive contamination of the environment. It reaffirmed the responsibility of health agencies to maintain appropriate surveillance networks to provide continuing information of levels of environmental contamination affecting the public. It also emphasized the need to undertake broad research programs to develop countermeasures for the control of environmental contamination.

Morgan (*64*) has suggested for consideration a possible allocation of permissible genetic and/or body exposure of the population from man-made sources of ionizing radiation. An adaptation of his tabulation is shown in table 13. Column three of the table presents doses that he believes can be attained by the application of proper technology and practices. These are long range projections; some of the values are larger and others, smaller than present estimates of population doses from the source.

Table 13. Suggested levels of permissible genetic and/or whole body exposure of the population

Source	Radiation levels (mrem/a)	
	"Permissible"	"Attainable"
Nuclear power operations:		
Internal dose	50	5
External dose	17	2
Other industrial operations:		
Internal dose	30	3
External dose	15	2
Medical exposure } diagnostic	50 } 40	10 } 5
therapeutic	10	5
Other occupational contributions to population dose	4	.1
Weapons fallout	2	
Miscellaneous (watches, television, high voltage switches, etc.)	2	.1
Total	~170	22

Additional exposures to individuals would include such things as 2 to 4 mrem for a commercial round-trip flight across the United States (*5*). Some doses to local populations may result from Plowshare operations or from nuclear rocket tests.

Discussion

A coordinated approach to the documentation and assessment of population exposure to environmental radiation from all sources is essential to the development of guidelines and countermeasures useful in minimizing hazards to public health. Federal agencies and most States have surveillance programs of varying degrees of adequacy. A continual evaluation to assess priorities based on magnitude and type of exposure and a program designed to improve our knowledge of the biological consequences of radiation constitute important features of the total public health responsibility. The information resulting from these programs, when made available in a responsible manner and on a timely basis, will provide the

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groundwork for scientific and public perspectives on the needs and consequences (the so-called "benefit-risk" calculations) relative to the applications of radiation.

At the present time and for the foreseeable future, the predominant exposure to the public is attributable to natural background and to medical x rays. Exposure to residual fallout radioactivity presents a declining hazard. Exposure to nuclear power operations and especially to medical radiation (x rays and internally administered radionuclides) is projected to become of increasing consequence and therefore warrants increased attention in planning for surveillance. In addition, surveillance associated with peaceful uses of nuclear engines should form a part of future programs.

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Public Health Aspects of Iodine-129 from the Nuclear Power Industry

John L. Russell and *Paul B. Hahn*[1]

The production of iodine-129 in nuclear power reactors and its subsequent environmental releases during fuel reprocessing represent a potential long-term public health problem. Because of its extremely long half-life, any discharged iodine-129 is essentially a permanent contaminant in the biosphere, where it will eventually be found as a fraction of total iodine within a locality and possibly worldwide. This potential problem, its possible geographical scope, and the projected impact on population exposure are discussed along with data from measurements at nuclear power reactors and a fuel reprocessing plant.

A concentration of 0.86 percent iodine-129 in total iodine produces the dose limit recommended by the Federal Radiation Council (FRC) for a suitable sample of an exposed population. The quantity of iodine-129 discharged from operating power reactors was estimated from measurements of iodine-131 discharges by calculating an iodine-129 to iodine-131 buildup ratio. This analysis showed that the iodine-129 discharge from operating power reactors was negligible. Measurements at a fuel reprocessing plant indicated that approximately 10 percent of the total iodine-129 inventory in spent fuel was discharged from the stack during the batch dissolution process. The liquid discharge concentrations were about 2 percent of the total iodine-129 inventory. Iodine-129 levels in deer thyroids taken in the reprocessing plant locality were about 40 percent of levels of FRC guidance for human thyroids.

The evaluation of potential public health hazards from the nuclear industry has traditionally followed the philosophy and guidance developed during the fallout era, when massive amounts of fresh fission products were released into the atmosphere. This guidance has proven quite satisfactory to date, leading as it has, to a protection record that is unequaled in the development stages of any other technology. However, the rapid growth of the nuclear power industry and predictions that the growth will continue require radiation protection planning beyond the experience and guidance obtained from the days of fallout measurements.

One of the problems produced by the proliferation of nuclear power is the increase in the number of significant radionuclides in terms of exposure to man. Added to the list of potentially hazardous radionuclides from atmospheric testing of nuclear explosives are cesium-134, iodine-129, krypton-85, tritium, and activation products. While these radionuclides are not exclusively produced by nuclear power, their relative significance, in terms of exposure to man, has generally increased due to the production of nuclear power.

The evaluation of many of these newly significant radionuclides in now underway. One of these radionuclides, iodine-129, presents unique interpretive problems because of its extremely long half-life.

Predictions of natural iodine-129 concentrations in sea water, in the atmosphere, and in the terrestrial environment were made by Edward (*1*) who also discussed measurement sensitivity and the use of iodine-129 as a tracer. Results of $^{129}I/^{127}I$ measurements (*2-3*) confirm Edward's prediction that nuclear explosions have contributed substantial amounts of iodine-129 to the environment. However, iodine-129 produced by the nuclear power industry has not been widely investigated.

This paper presents a review of this potential public health problem, its possible geographical scope, the projected impact on population exposure, and a discussion of rather limited environmental data.

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Potential hazard evaluation of iodine-129

Four characteristics of radioactive iodine-129 are important in evaluating its potential hazard to man:

1. Nuclear fission yield of approximately 1 percent, making it relatively abundant;
2. Extremely long half-life of 1.7×10^7 years, making it a permanent local, and possibly worldwide, contaminant;
3. Low beta energy and low gamma energy emitter, making detection and measurement difficult; and
4. Physiological concentration in the thyroid.

In general, there are three approaches available to evaluate the hazards of iodine-129: the Critical Pathway Approach, the Specific Activity Approach, and the Point of Discharge Approach (*4*). The Specific Activity Approach as originally developed by a National Academy of Sciences-National Research Council study (*5*) and discussed in depth by Kaye and Nelson (*6*) appears the most appropriate method and is used in this paper for reasons that will become apparent.

The specific activity may be defined as the ratio of radioactive atoms to total atoms of the same element or as activity per unit of the element (e.g. Ci/g). For this paper the definitions are:

R_t = ratio of iodine-129 atoms to total iodine atoms for a limiting dose to the thyroid as defined by International Commission on Radiological Protection and Federal Radiation Council (*7, 8*)

SpA = curies per gram of iodine-129 (constant) $= 1.63\times10^{-4}$

lim SpA = curies of iodine-129 per gram of total iodine for a limiting dose to the thyroid as defined by the ICRP and the FRC (*7, 8*).

The specific activity concept is based on the fact that the chemistry of radioactive and stable elements is identical. Thus, at equilibirum conditions the ratio of radioactive atoms to total atoms is constant in all media in the pathway of interest. This is the most conservative consideration in keeping with the philosophy of radiation protection since it assumes that man's total intake of iodine is from this one particular ecological chain. By using appropriate guidance (*7*) for the dose to the critical organ in man, the limiting ratio can be calculated. This concept is subject to the assumptions:

1. Identical physiological characteristics of stable and radioactive atoms of the same element;
2. Complete mixing of stable and radioactive atoms; and
3. Equilibrium conditions necessitating constant intake and discharge, relatively long half-life, etc.

In addition, sufficient information on the biological and physical parameters is needed to perform the dose analysis. The major limitation of the method is that it accounts for the dose to a critical organ from one radionuclide only and does not include organ dose from other sources (*6*).

Using ICRP recommendations (*7*) and data for standard man, the specific activity for Maximum Permissible Occupational Exposure is calculated:

$$\text{lim SpA} = \frac{(q)(f_2)}{(C)(w)}$$

where: q = maximum permissible burden of iodine-129 in the whole body (3 μCi)

f_2 = fraction in thyroid to that in whole body (0.2)

C = average concentration of stable iodine in the critical organ (350 μg/g wet tissue)

w = weight of thyroid in standard man (20 g)

The ratio of iodine-129 atoms to total iodine atoms (R_t) for the particular lim SpA is then calculated:

$$R_t = \frac{\text{lim SpA } ^{129}\text{I}}{\text{SpA } ^{129}\text{I}} = \frac{\text{g of } ^{129}\text{I}}{\text{g of total iodine}}$$

These calculations have also been performed for FRC guidance (*8*) and the results are listed in table 1.

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Table 1. lim SpA and R_t for iodine-129 in the 20 gram human thyroid at various recommended dose limits

Thyroid dose (rem/a)	Body burden (μCi)	Thyroid burden (μCi)	lim SpA iodine-129 (μCi/g total iodine)	R_t (iodine-129/total iodine)
30.	3.	0.6	86.	0.58
1.5	.15	.03	4.3	.029
.5	.05	.01	1.4	.0096

From table 1, it is observed that the standard man will receive 1.5 rem/a to his thyroid if 2.6 percent of the iodine in his body is iodine-129 averaged over the year. Because the biological half-life of iodine is 138 days, a constant intake of iodine-129 is required to maintain a given ratio (R_t) in the body. It is here that the specific activity approach becomes useful. Since the ratio is assumed constant for the ecological chain, measurements can be made at any point in the chain and the potential hazard evaluated through comparisons with lim SpA or R_t ratios in table 1. This assumption is conservative since it represents the worst possible case.

This approach obviously cannot be used for intake by inhalation or in the airborne segment of the air-grass-cow-milk-man pathways because of the many complexities involved in mixing, sampling, intake, etc. However, other investigators have reported that the dose to the thyroid from iodine inhalation is small where iodine also exists in the food chain (*9,10*). The sensitivity of air sample measurements is generally low, thereby making it an inefficient sampling medium and of questionable use when attempting to establish environmental concentrations of radioactivity. It is concluded that the specific activity approach can be utilized when evaluating the chronic long-term hazards to man from iodine-129.

Production and buildup of iodine-129 from the nuclear power industry

The projected accumulated total iodine-129 produced by worldwide nuclear power from 1965 to 2060 and by United States nuclear power from 1965 to 2020 is depicted in figure 1. World power production estimates are from Coleman and Liberace (*11*), with slight modification. The total power estimate is the same but introduction of the breeder-type reactor is changed to a later date. Estimates of United States power production are from a National Air Pollution Control Administration report (*12*).

The fission yield (*13*) of iodine-129 varies by a factor of about 3 depending on the fission process. Since this variability can induce large errors in estimates of iodine-129 production, it is estimated that 40 percent of the power from uranium-235 thermal reactors is from the use of plutonium-239 while 60 percent of the power is from uranium-235. Plutonium-239 fast breeder reactors and uranium-233 thermal reactors are estimated to produce significant amounts of iodine-129 by about 1985. By 2105 more iodine-129 will be produced annually by plutonium breeder reactors than by thermal uranium-235 reactors, including the 40 percent plutonium-239 thermal contribution.

Since the decay of iodine-129 can be ignored, the long-term buildup of iodine-129 becomes appreciable. The total amount produced worldwide by 2060 will be 2 MCi, and the amount produced in 2060 will be 90 kCi. Assuming an overall removal efficiency of 99 percent, there could be 20 kCi or 120 Mg of iodine-129 in the environment in 2060. Using FRC guidance for a suitable sample of the exposed population (where lim SpA ^{129}I = 1.4 μCi/g), 14 Gg of stable iodine will be required for dilution of the iodine-129 released. Although much larger quantities of stable iodine are present in the environment, it is not known how much of this iodine would be available for dilution.

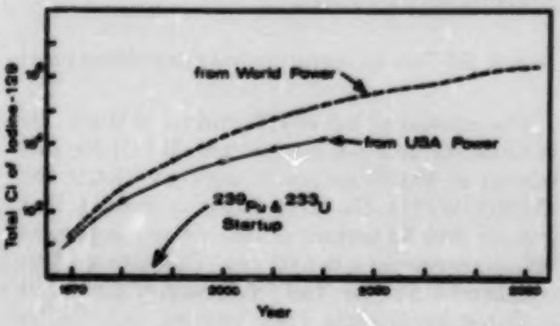

Figure 1. Accumulated iodine-129 from nuclear power

Iodine-129 from operating reactors

Iodine-129 data are not available from operating reactors generally because most iodine-129 is removed during waste treatment procedures which also remove iodine-131. However, a method of analysis using iodine-131 measurements and an iodine-129 to iodine-131 in core concentration ratio appears feasible since it is suspected the isotopes of iodine will behave similarly. The ratio of the activities of iodine-129 to iodine-131 in core is about 10^{-8} after 1 year of operation, assuming equilibrium conditions for iodine-131. Kahn (*14, 15*) has reported data on iodine-131 atmospheric discharges from Dresden 1 and Yankee:

Dresden 1: Iodine-131 stack discharge = 920 pCi/s = 29 mCi/a, then iodine-129 stack discharge ≈ 300 pCi/a
Yankee: Iodine-131 stack discharge = <10 pCi/s = <320 μCi/a, then iodine-129 stack discharge ≈ 3 pCi/a

Little significance can be attached to the Yankee iodine-131 data, since the iodine-131 results were less than the 3-sigma counting error. Kahn (*15*) concluded that no particulate or gaseous iodine-131 was detected in any sample. The relatively long holdup time in the waste gas storage tanks permitted decay of most of the iodine-131. Since the holdup time at Dresden 1 was only 30 minutes, iodine-131 decay is negligible and the estimate appears valid.

However, these small quantities appear inconsequential, and it is concluded that no public health hazard exists at the present time due to gaseous discharge of iodine-129 from nuclear power plants themselves.

Iodine-129 from an operating fuel reprocessing plant

The amount of iodine-129 present in spent fuel is about 40 mCi per metric ton (MTU) for fuel burned at 40,000 megawatt days per metric ton (MWD/MTU). Cladding integrity insures that greater than 99 percent of this activity is present before reprocessing is initiated. The nation's first commercial nuclear fuel reprocessing facility is operated by Nuclear Fuel Services, Inc. (NFS) and is located at West Valley, N.Y. Limited surveillance data for iodine-129 from this plant have been evaluated using the specific activity approach. The NFS plant routinely reports liquid waste discharges of iodine-129 (*16*). The iodine-129 discharged in the liquid waste is about 100 mCi/a, or approximately 2 percent of the total iodine-129 present in the fuel processed each year. Although this is a small percentage, it must be evaluated in context with the environmental buildup and stable iodine available for dilution, as discussed previously.

A weed sample collected in Cattaraugus Creek about 1 mile downstream of NFS discharge contained 0.81 μCi ^{129}I/g of total iodine, or 58 percent of FRC guidance for a suitable sample of an exposed population using the specific activity approach. This approach is conservative since it assumes that a man's total iodine intake would be from the ecological chain containing this weed as an integral part and that the ratio of iodine-129 to stable iodine is at equilibrium throughout the chain. Under these circumstances, the maximum dose to a man's thyroid from iodine-129 would be 58 percent of 0.5 rem/a. This finding indicates a possible concentration process as reported by others (*17*). Obviously there is a need for more information concerning the ecological behavior of iodine in aquatic systems.

Cochran et al. (*18*) have reported results of iodine-129 measurements of the gaseous waste discharge at Nuclear Fuel Services. The results of gaseous discharge samples collected during the fuel dissolution process indicate that 5 to 10 percent of the iodine-129 in each batch is discharged through the stack. Extreme caution should be used in evaluating these measurements considering:

1. The sampling was only conducted during the 4-hour dissolution process;
2. A considerable percentage of the iodine is suspected to be released during the nitric acid recovery processes; and
3. The sampling system itself suffered from many problems, such as plate-out of the iodine on the interior wall of the sampling pipe during its long run down the stack, across the roof, and into the sampling system which is inside the building.

Cochran lists additional problems.

Weighing these factors, along with the measurements, indicates that a rather high percentage of the iodine-129 is probably discharged as gaseous waste. This percentage is quite likely about 90 percent.

Mention should be made of the fact that NFS was not using their iodine removal equipment during these studies since the fuel being processed had cooled for over a year and the iodine-131 had decayed to inconsequential levels. Removal efficiency for iodine is estimated at 99.5 percent for the NFS scrubbers.

A large amount of work has been performed on the general matter of release of gaseous iodine and its subsequent behavior in the environment. The many complexities involved in evaluating the behavior of iodine in its pathways to man lead to very few general conclusions. However, it appears that a large fraction of the iodine is removed from the air within a relatively short distance from the discharge point *(10)*. Thus, it is concluded that the iodine-129 released from a reprocessing plant will settle out and mix with the stable iodine within the immediate plant environs, and the gaseous iodine-129 discharge can be considered a local problem. Confirmation of this conclusion should be obtained by analyzing environmental samples from the immediate vicinity of the plant for iodine-129 and stable iodine. The immediate vicinity is within a 20-mile radius of the plant for purposes of this discussion. However, the liquid releases may have a much larger geographical impact.

The New York State Department of Health has analyzed thyroids from deer collected in the NFS environs and reports iodine-129 concentrations ranging from nondetectable to 210 pCi ^{129}I/g of thyroid for 1968 and 1969 *(19)*. Assuming the same total iodine concentration in a deer thyroid as in humans, this 210 pCi/g measurement is 43 percent of FRC guidance for a suitable sample of an exposed population. Because of intake considerations, this value should not be translated in terms of human dose. It appears that a local buildup of iodine-129 is taking place around NFS. However, there is some question concerning the intake pathway of these samples since the deer have access to water from Buttermilk and Cattaraugus Creeks. Thyroid samples from cows, rabbits, groundhogs, and other animals selected from areas precluding consumption of water from the creeks may be more representative of the air pathway.

Summary and conclusions

A method of evaluating the dosimetric significance to man from iodine-129 discharged by the nuclear power industry was developed. Radiation protection recommendations of the ICRP and standard man data were used to develop an iodine-129 to total iodine ratio which can serve as a guide for evaluating environmental surveillance data at various dose levels. Estimates were made of the total iodine-129 production by the nuclear power industry on both a worldwide and a nationwide basis. Application of the method to discharge data available from operating nuclear power plants indicated that there is currently no hazard from their discharge of iodine-129. However, when the method was applied to limited surveillance data around a nuclear fuel reprocessing plant, specific activities were found to be at levels corresponding to a considerable fraction of FRC guidance for a suitable sample of the exposed population.

Since the addition of iodine-129 to the environment is an unretrievable use of natural resources, it is concluded that efforts should be undertaken to reduce the long-term accumulation of this radionuclide in the environment. In order to accomplish this reduction, information should be developed on the behavior of iodine during the various reprocessing cycles. In addition, more information is required to fully evaluate the extent of iodine-129 concentrations in environmental media around nuclear fuel reprocessing plants. The behavior of iodine in aquatic ecosystems requires investigation. When analyzing samples for iodine-129, stable iodine concentrations should also be determined in order that the specific activity approach can be used to evaluate the public health impact.

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Statistical Limits of Accuracy and Precision of Gross Alpha and Beta Radioactivity Measurements in Water

Edmond J. Baratta and *Forrest E. Knowles, Jr.*[1]

This paper presents the results of a technical experiment designed to determine the effectiveness of measurements for gross alpha and beta radioactivity in water. Since this analysis is normally used as a "screening" technique, it is essential that the limits of precision and accuracy of the method be known. Gross measurements are still being used in preoperational reactor surveys as an indication of the "background" levels and to monitor radioactivity when the reactor becomes operational. In addition, the Public Health Service standard for drinking water has, in lieu of a determination of radium-226 and strontium-90, limits for gross alpha and beta radioactivity, respectively.

The precision and accuracy of a standard method for analysis of gross alpha and beta radioactivity in water were determined through the cooperation of private and government laboratories. It was found that gross alpha radioactivity could be determined with an overall precision of 12 percent, while the gross beta radioactivity could be determined with a precision of 7 percent. The accuracy of the gross alpha activity measurements was within 10 percent, and for the gross beta activity measurements, 1 percent.

A technical experiment designed to determine the detection limits, accuracy and precision of gross alpha and beta radioactivity measurements in water was conducted by the Environmental Protection Agency's Analytical Quality Control Service at the Northeastern Radiological Health Laboratory. These analyses are normally used as a "screening" technique. Since they are used as such, it is desirable to know the limits of accuracy and precision. These measurements are routinely made by the State Health Departments and Power Companies around areas proposed as reactor sites and fuel reprocessing plants in order to establish a background survey. When the nuclear facilities become operational, the gross alpha and beta measurements are made to monitor the effluent from the plants. These are performed routinely since they are fairly inexpensive to make, as compared with specific analyses of the radionuclides present.

The Public Health Service also has found these measurements very useful as a screening technique (*1*). For guidance on drinking water, it has established an alpha limit of 3 pCi/liter and a beta limit of 10 pCi/liter before specific analyses are made. If gross alpha radioactivity is above 3 pCi/liter, then a specific analysis is made for radium-226. If gross beta radioactivity is above 10 pCi/liter, then a specific analysis is made for strontium-90.

Preparation of samples and description of test

Test materials for this experiment consisted of a standard solution of alpha radioactivity, a standard solution of beta radioactivity and tap water for a source of dissolved solids. The alpha activity was natural uranium and the beta activity was cesium-137. These solutions were dilutions of stock activity prepared in acid solution so as to eliminate loss of activity on the walls of vials. The supplied tap water was drinking water from Woburn, Mass., with a solids content of 350 mg/liter. Two pairs of samples containing different levels of radioactivity were prepared from the alpha and beta solutions. The concentrations in these samples are described in table 1.

Five ml portions of each alpha and beta solution and 4 liters of the drinking water were forwarded to the participants. In addition, cesium-

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137 and natural uranium calibration solutions were forwarded for use in preparation of absorption curves. The participants were instructed to pipet 1 ml of each alpha solution and 1 ml of each beta solution into separate appropriate aliquots of supplied water. A single analysis was to be performed for each sample.

Table 1. Radioactivity in test samples[a]

Radioactivity	Pair 1		Pair 2	
	Sample R	Sample S	Sample T	Sample U
Alpha (pCi natural U/sample[b])	37.9	25.4	100.2	80.5
Beta (pCi ^{137}Cs/sample)	62.5	47.7	130.0	156.0

[a] The accuracy of the standards were within ±2 percent.

[b] pCi/sample refers to picocuries per 1 milliliter of supplied alpha and beta activity.

Methodology

Procedures used to measure the gross alpha and gross beta activities were taken from the 12th Edition of the American Public Health Association (APHA) Standard Methods (*2*). Analysis of gross alpha and beta radioactivity is as follows: The specific conductance is measured first to help select the proper sample volume. The sample is prepared by (1) adding sample directly to a tared counting pan with evaporation just below the boiling temperature, or (2) placing the sample in a pyrex beaker, adjusting the pH to 4–6, and evaporating to near dryness. The residue is transferred to a tared counting pan using water and dilute acid washings.

The counting pan is dried in an oven at 103–105° C, cooled in a desiccator, weighed, and kept dry until counted. The sample is counted in an internal proportional counter or other appropriate counting instrument.

Analysis of data

The results of the gross alpha test are presented in table 2. The results of the gross beta test are presented in table 3. The design and evaluation of these tests are based in part on Youden's guide on "Statistical Techniques for Collaborative Tests" (*3*). This design assumes that the internal precision is not different at each laboratory, and the differences which usually exist between laboratories are associated with laboratory systematic errors.

Table 2. Gross alpha radioactivity in water

Laboratory code[a]	Results (pCi/sample)			
	Sample R	Sample S	Sample T	Sample U
E	40.4	28.3	97.3	78.8
G	14.9	10.6	34.9	31.7
I	34.0	23.8	91.4	73.8
J	35.5	21.5	90.7	77.5
M	35.3	26.4	83.2	65.2
N	57.8	34.6	155.7	112.0
O	24.2	20.5	44.7	25.0
Q	34.8	25.3	85.4	76.7
R	33.0	22.8	65.0	67.6
S	15.1	12.3	53.4	28.4
T	36.1	24.0	97.3	78.8
V	48.3	29.5	135.7	107.8
X	42.1	27.2	120.8	89.8
Y[b]	4.63	3.58	15.6	11.3
Average	34.7	23.6	88.9	70.2
Range	42.9	24.0	120.8	87.0
Known	37.9	25.4	100.2	80.5

[a] Laboratory code P and AA did not participate in this analysis.

[b] Not included in range or average.

Table 3. Gross beta radioactivity in water

Laboratory code	Results (pCi/sample)			
	Sample R	Sample S	Sample T	Sample U
E	67.5	54.1	146.0	168.8
G	39.2	46.6	54.5	116.0
I	43.2	39.6	108.5	139.6
J	62.0	49.6	125.5	155.3
M	93.5	78.4	217.0	234.0
N	78.8	65.2	170.7	200.4
O	50.7	34.4	111.2	119.7
P	68.8	45.5	131.0	156.0
Q	66.8	51.7	135.3	157.1
R	61.6	52.6	125.4	151.2
S	64.2	49.5	126.3	142.8
T	65.4	51.5	127.4	155.0
V	55.4	45.4	118.2	152.7
X	59.9	48.6	128.2	154.4
Y	49.3	39.0	103.0	122.0
AA	59.5	47.4	134.9	152.0
Average	61.6	49.9	128.9	154.8
Range	54.3	44.0	162.5	118.0
Known	62.5	47.7	130.0	156.0

There are three distributions which are of interest: S_d—the combined effect of the distribution of systematic errors and the random errors associated with the individual results. S_a—a measure of how successful repeat determinations can be made (degree of random error). S_b—a measure of the displacement (or change in bias) that may be encountered as one changes laboratories (or degree of laboratory systematic error). The distribution has the following relationship:

$$S_d^2 = S_b^2 + S_a^2 \qquad \ldots(1)$$

The actual data yield S_d^2 and S_a^2. S_b^2 is determined by difference. The following formulas were used to make the various calculations:

$$S_d = \sqrt{\frac{(T_i - \bar{T})^2}{2(n-1)}} \qquad \ldots(2)$$

T_i = Total of the paired samples for the "i"th lab
$\bar{T}$ = average total
n = number of totals

$$S_a = \sqrt{\frac{(D_i - \bar{D})^2}{2(n-1)}} \qquad \ldots(3)$$

D_i = difference between paired samples for the "i"th lab
$\bar{D}$ = average difference
n = number of differences

An estimate of the method accuracy is obtained by the difference between the average known concentration and the average found concentration for each pair. The relative accuracy is calculated by dividing this difference by the average known concentration. Relative precision for the method is estimated by dividing the random error (S_a) by the average amount found for each pair. This statistical analysis for the gross alpha and beta radioactivity is presented in tables 4 and 5, respectively. The summary for gross alpha and beta radioactivity is presented in table 6.

Table 4. Data analysis, gross alpha radioactivity in water

Laboratory code[a]	Difference (R−S)	Total (R+S)	Difference (T−U)	Total (T+U)
Known	12.5	63.3	19.7	180.7
E	12.1	68.7	18.5	176.1
G	4.3	25.5	3.2	66.6
I	10.2	57.8	17.6	165.2
J	14.0	57.0	13.2	168.2
M	8.9	61.7	18.0	148.4
N	23.2	92.4	43.7	267.7
O	3.7	44.7	19.7	69.7
Q	9.5	60.1	8.7	162.1
R	10.2	55.8	−2.6	132.6
S	2.8	27.4	25.0	81.8
T	12.1	60.1	18.5	176.1
V	18.8	77.8	27.9	243.5
X	14.9	69.3	31.0	210.6
Total	144.7	758.3	242.4	2,068.6
Average	11.1	58.3	18.6	159.1
S_a^2	17.1		72.0	
S_a	4.1		8.5	
S_d^2		167.3		1,901
S_d		12.9		43.6

[a] Laboratory Y was not included in data analysis.

Table 5. Data analysis, gross beta radioactivity in water

Laboratory code	Difference (R−S)	Total (R+S)	Difference (U−T)	Total (U+T)
Known	14.8	110.2	26.0	286.0
E	13.4	121.6	22.8	314.8
G	−7.4	85.8	61.5	170.5
I	3.6	82.8	31.1	248.1
J	12.4	111.6	29.8	280.8
M	13.1	171.9	17.0	451.0
N	13.6	144.0	29.7	371.1
O	16.3	85.1	8.5	230.9
P	23.3	114.3	25.0	287.0
Q	15.1	118.5	21.8	292.4
R	9.0	114.2	25.8	276.6
S	14.7	113.7	16.5	269.1
T	13.9	116.9	27.6	282.4
V	10.0	100.8	34.5	270.9
X	11.3	108.5	26.2	282.6
Y	10.3	88.3	19.0	225.0
AA	12.1	106.9	17.1	286.9
Total	186.7	1.784.9	413.9	4,540.1
Average	11.7	111.6	25.8	283.8
S_a^2	21.4		67.5	
S_a	4.6		8.2	
S_d^2		259.0		1.014.9
S_d		16.1		43.8

Discussion of results

Accuracy and precision for this method were determined using the data from all contributing laboratories except in the case of gross alpha radioactivity where one outlying laboratory was not included. For both alpha and beta determinations, there were some laboratories which could have been excluded from the data analysis due to their deviation from the known but were included to keep the number of laboratories at a maximum.

The gross alpha determination appears to be biased low, as observed from the differences the average amount present and the average amount found. The accuracy ranges from minus 8 percent to 12 percent and the precision ranges from 11 percent to 14 percent. In most cases the laboratories did quite well in determining the difference between the paired samples. In the

Table 6. Summary of results

Pair	Average amount found	Average amount present	Difference amount present-amount found	S_a	$\frac{S_a \times 100}{\text{Average amount found}}$
Gross alpha radioactivity in water:					
1	29.2	31.7	2.5	4.1	14.0
2	79.6	90.4	10.8	8.5	10.7
Gross beta radioactivity in water:					
1	55.8	55.1	−0.7	4.6	8.2
2	141.9	143.0	1.1	8.2	5.8

absence of laboratory systematic error, S_a and S_d are estimates of the same within laboratory precision. S_a is substantially smaller than S_d for sample pairs which indicates the presence of some degree of laboratory systematic error. Possible explanations for the low bias are (1) problems in self-absorption since some laboratories experienced excessive weights of solids, and (2) incomplete drying of samples.

The gross beta results did not show any bias. The average amount present and average amount found were nearly identical for both pairs. The accuracy is about 1 percent and the precision ranges from 6 percent to 8 percent. The laboratories did well in determining the differences between the paired samples. Laboratory systematic errors are present in some degree since S_a is substantially less than S_d for both sample pairs. Problems in solids preparation were experienced by some of the laboratories but did not appear to be serious.

The results of the technical experiment show that this procedure for gross alpha and beta determination is acceptable as a standard method. As a screening technique, the procedure performed better than expected and could be applied to limits for specific radionuclides. The only problem appears to be in amount of solids present but if the suggested aliquot size and drying technique is followed carefully, it should not be serious.

Samples with activities around 3 pCi/liter for alpha and 10 pCi/liter for beta have not been used for a technical experiment. These levels have been used in the Analytical Quality Control Service cross-check water program. (*4*) The results of samples in that program with activities similar to the samples in this technical experiment have been comparable.

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SECTION I. MILK AND FOOD

Milk Surveillance, December 1970

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption can be readily obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Radiation Office, Environmental Protection Agency, and the Office of Food Sanitation, Food and Drug Administration, U.S. Public Health Service, consists of 63 sampling stations; 61 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State Health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiological Health Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Environmental Protection Agency)—5 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations

The sampling locations that make up the networks presently reporting in *Radiological Health Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that are formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of

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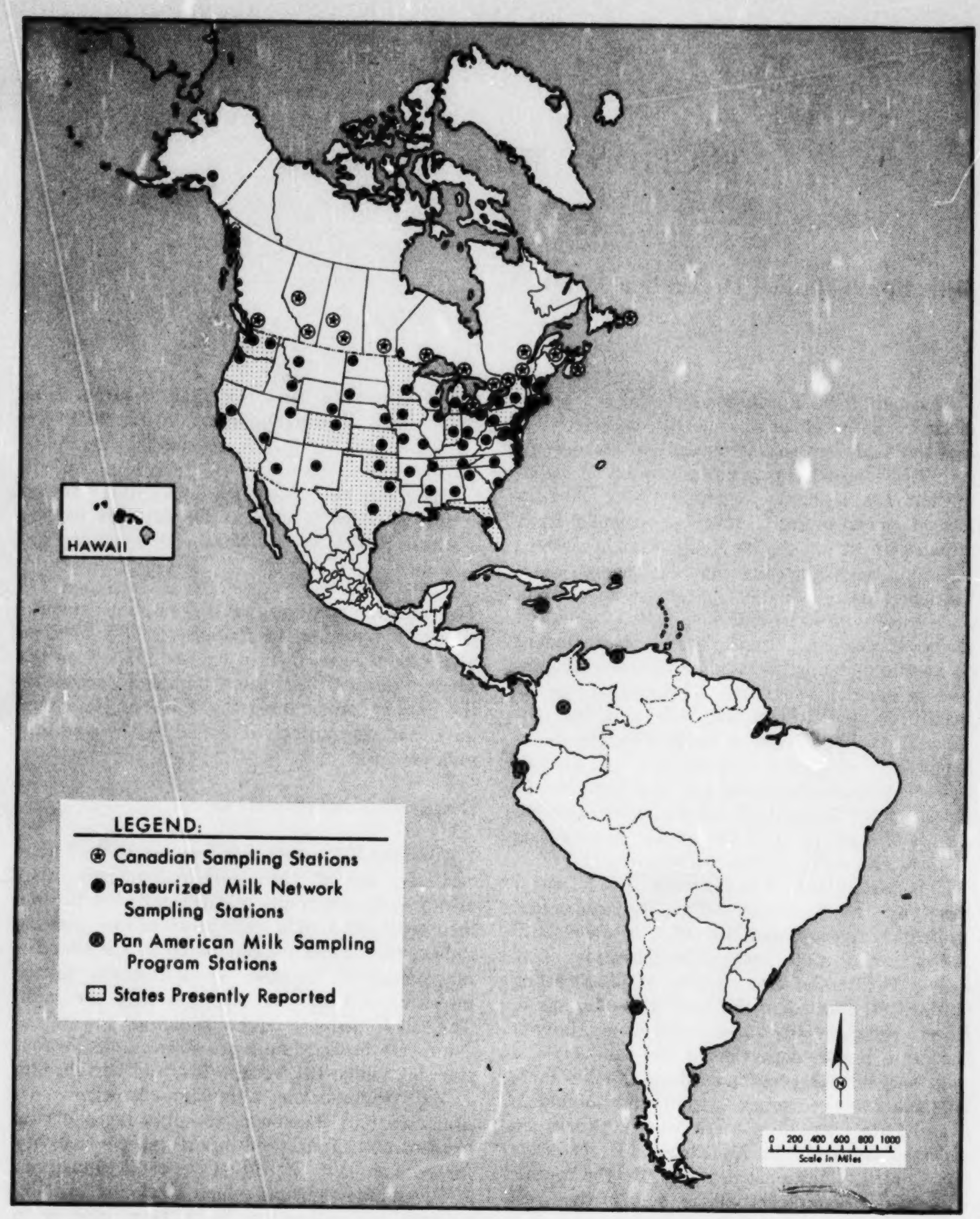
HAWAII
LEGEND:
⊛ Canadian Sampling Stations
● Pasteurized Milk Network Sampling Stations
⊗ Pan American Milk Sampling Program Stations
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Scale in Miles

Figure 1. Milk sampling networks in the Western Hemisphere

metabolically similar radionuclides (radiostrontium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variations, expressed in terms of 2-standard deviations (2σ), for these elements are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for May 1963–March 1966 (*3*) and were determined for use in general radiological health calculations or discussions.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Bureau of Radiological Health conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested public health radiochemical laboratories. The generalized procedure for making such a study has been outlined previously (*4*).

The most recent study was conducted during May–July 1970, with 28 laboratories participating in an experiment on milk samples containing known concentrations of strontium-89, strontium-90, iodine-131, cesium-137, and barium-140 (*5*). Of the 20 laboratories producing data for the networks reporting in *Radiological Health Data and Reports*, 13 participated in the experiment.

The accuracy results of this experiment are shown in table 1. In general, considerable improvement is needed, especially in the accuracy measurements. These possible differences should be kept in mind when considering the integration of data from the various networks.

Development of a common reporting basis

Since the various networks collect and analyze differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methods, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole

Table 1. Distribution of mean results, quality control experiment

Isotope and known concentration		Number of laboratories in each category			
		Acceptable[a]	Warning level[b]	Unacceptable[c]	Total
Strontium-89:	High (258 pCi/liter)	7 (44%)	1 (6%)	8 (50%)	16
	Low (15 pCi/liter)	11 (69%)	3 (19%)	2 (12%)	16
Strontium-90:	Intermediate (79.4 pCi/liter)	13 (57%)	4 (17%)	6 (26%)	23
	Low (32.0 pCi/liter)	5 (25%)	4 (20%)	11 (55%)	20
Iodine-131:	High (507 pCi/liter)	18 (67%)	2 (7%)	7 (26%)	27
	Low (49 pCi/liter)	16 (64%)	3 (12%)	6 (24%)	25
Cesium-137:	High (259 pCi/liter)	20 (74%)	3 (11%)	4 (15%)	27
	Low (53 pCi/liter)	17 (66%)	5 (19%)	4 (15%)	26
Barium-140:	High (302 pCi/liter)	18 (67%)	2 (7%)	7 (26%)	27
	Low (33 pCi/liter)	23 (92%)	0	2 (8%)	25

[a] Measured concentration less than or equal to 2σ of the known concentration.

[b] Measured concentration greater than 2σ and less than or equal to 3σ of the known concentration.

[c] Measured concentration greater than 3σ of the known concentration.

milk. Each laboratory has its own modifications and refinements of these basic methodologies. The methods used by each of the networks have been referenced in earlier reports appearing in *Radiological Health Data and Reports*.

A previous article (*6*) summarized the criteria used by the State networks in setting up their milk sampling activities and their sample collection procedures as determined during a 1965 survey. This reference and earlier data article for the particular network of interest may be consulted should events require a more definitive analysis of milk production and milk consumption coverage afforded by a specific network.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. Many networks are analyzing composite samples on a quarterly basis for certain nuclides. The frequency of collection and analysis varies not only among the networks but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short time periods, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and is generally increased at the first measurement or recognition of a new influx of this radionuclide.

The data presentation also reflects whether raw or pasteurized milk was collected. An analysis (*7*) of raw and pasteurized milk samples collected during January 1964 to June 1966 indicated that, for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant (*7*). Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard deviation counting errors or 2-standard deviation total analytical errors from replicate analyses (*3*). The practical reporting level reflects analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases, the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below these practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical error or precision expressed as pCi/liter or percent in a given concentration range have also been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2-standard deviations)
Strontium-89	1–5 pCi/liter for levels <50 pCi/liter; 5–10% for levels ≥50 pCi/liter;
Strontium-90	1–2 pCi/liter for levels <20 pCi/liter; 4–10% for levels ≥20 pCi/liter;
Iodine-131 Cesium-137 Barium-140	4–10 pCi/liter for levels <100 pCi/liter; 4–10% for levels ≥100 pCi/liter.

For iodine-131, cesium-137, and barium-140, there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the U.S. data on radioactivity in milk presented in *Radiological Health Data and Reports* in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions was presented in the December 1970 issue of *Radiological Health Data and Reports.*

Data reporting format

Table 2 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are routinely reported to *Radiological Health Data and Reports.* The relationship between the PMN stations and the State stations is shown in figure 2. The first column under each of the reported radionuclides gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed populations groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 2, surveillance results are given for strontium-90, iodine-131, and cesium-137 for December 1970 and the 12-month period, January 1970 to December 1970. Except where noted, the

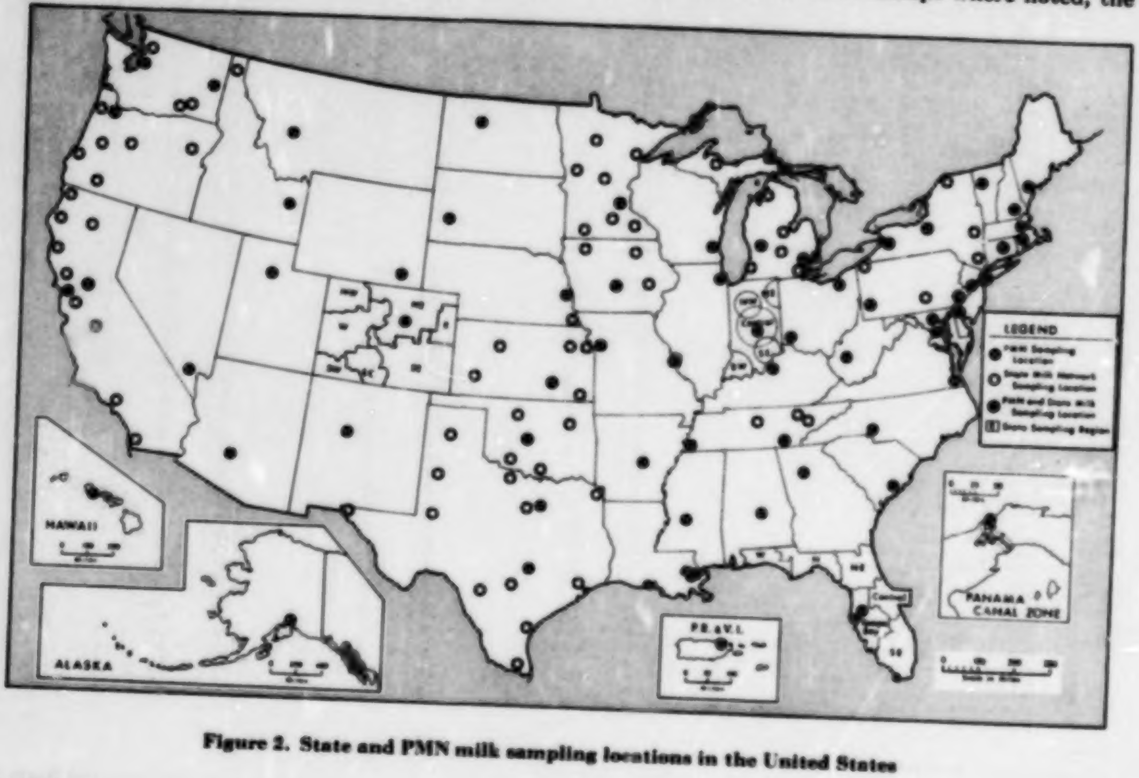

Figure 2. State and PMN milk sampling locations in the United States

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Table 2. Concentrations of radionuclides in milk for December 1970 and 12-month period, January 1970 through December 1970

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES:								
Ala:	Montgomery[a]	P	NA	6	0	0	0	8
Alaska:	Palmer[a]	P	4	6	0	0	0	9
Ariz:	Phoenix[a]	P	NA	1	0	0	0	0
Ark:	Little Rock[a]	P	12	13	0	0	0	15
Calif:	Sacramento[a]	P	NA	2	0	0	0	0
	San Francisco[a]	P	NA	2	0	0	0	0
	Del Norte	P	10	17	0	0	13	15
	Fresno	P	2	2	0	0	0	1
	Humboldt	P	6	5	0	0	0	5
	Los Angeles	P	2	2	0	0	0	2
	Mendocino	P	3	3	0	0	0	2
	Sacramento	P	3	3	0	0	0	2
	San Diego	P	2	2	0	0	0	1
	Santa Clara	P	2	2	0	0	0	1
	Shasta	P	2	3	0	0	0	2
	Sonoma	P	2	3	0	0	0	2
Colo:	Denver[a]	P	5 (2)	5	0 (3)	0	0 (3)	1
	West	R	[d]		[e]0 (10)	[e]0	[e]0 (10)	[e]3
	Northeast	R	[d]		[e]0 (4)	[e]0	[e]0 (4)	[e]0
	East	R	[d]		[e]0 (2)	[e]0	[e]0 (2)	[e]0
	Southeast	R	[d]		[e]0	[e]0	[e]0	[e]0
	South Central	R	[d]		NS	NS	NS	NS
	Southwest	R	[d]		[e]0	[e]0	[e]0	[e]0
	Northwest	R	[d]		[e]0	[e]0	[e]0	5
Conn:	Hartford[a]	P	NA	8	0	0	16	11
	Central	P	NA	7	0	0	10	14
Del:	Wilmington[a]	P	NA	9	0	0	0	7
D.C:	Washington[a]	P	NA	7	0	0	11	7
Fla:	Tampa[a]	P	6	6	0	0	53	51
	West	R	6	9	0	0	20	17
	North	R	14	12	0	0	30	26
	Northeast	R	6	6	0	0	39	40
	Central	R	8	7	0	0	44	49
	Tampa Bay area	R	6	6	0	0	51	50
	Southeast	R	7	7	0	0	43	75
Ga:	Atlanta[a]	P	NA	1[c]	0	0	0	14
Hawaii:	Honolulu[a]	P	3	2	0	0	0	0
Idaho:	Idaho Falls[a]	P	5 (3)	5	0 (3)	0	4 (3)	6
Ill:	Chicago[a]	P	6	7	0	0	19	11
Ind:	Indianapolis[a]	P	NA	8	0	0	0	6
	Northeast	P	10	10	0	1	10	13
	Southeast	P	9	11	0	0	10	12
	Central	P	8	9	40	3	15	10
	Southwest	P	14	12	0	0	0	11
	Northwest	P	10	11	0	0	0	13
Iowa:	Des Moines[a]	P	NA	7	0	0	0	2
	Iowa City	P	8	8	0 (2)	0	19 (2)	12
	Des Moines	P	6	8	0 (4)	0	15 (4)	9
	Spencer	P	4	6	0	0	0	7
	Fredericksburg	P	NS	NS	NS	NS	NS	NS
Kans:	Wichita[a]	P	NA	8	0	0	0	3
	Coffeyville	P	7	9	0	2	12	2
	Dodge City	P	9	7	0	0	0	1
	Falls City	R	NS	13	NS	3	NS	4
	Hays	P	NS	13	NS	2	NS	1
	Kansas City	P	8	8	0	0	13	5
	Topeka	P	8	10	0	2	14	4
	Wichita	P	12	12	0	0	0	1
Ky:	Louisville[a]	P	NA	9	0	0	0	4
La:	New Orleans[a]	P	14	14	0	0	11	19
Maine:	Portland[a]	P	NA	10	0	0	19	22
Md:	Baltimore[a]	P	NA	7	0	0	0	6
Mass:	Boston[a]	P	8	10	0	0	11	20
Mich:	Detroit[a]	P	NA	9	0	0	11	9
	Grand Rapids[a]	P	NA	9	0	0	21	12
	Bay City	P	NS	7	NS	[e]0	NS	11
	Charlevoix	P	NA	13	[e]0 (4)	1	14 (4)	16
	Detroit	P	NA	8	[e]0	[e]0	0	8
	Grand Rapids	P	NA	9	[e]0	[e]0	0	8
	Lansing	P	NA	9	[e]0 (2)	[e]0	14 (2)	14
	Marquette	P	NA	14	[e]0 (2)	[e]0	21 (2)	23
	Monroe	P	NA	6	[e]0 (2)	[e]0	0 (2)	3
	South Haven	R	NA	8	[e]0 (4)	[e]0	0 (4)	6
Minn:	Minneapolis[a]	P	NA	9	0	0	0	10
	Bemidji	P	8	9	0	0	18	21
	Mankato	P	5	5	0	0	9	11
	Rochester	P	7	6	0	0	14	12
	Duluth	P	NS	14	NS	0	NS	27
	Worthington	P	5	4	0	0	0	0
	Minneapolis	P	11	9	0	0	23	17

See footnotes at end of table.

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Table 2. Concentrations of radionuclides in milk for December 1970 and 12-month period, January 1970 through December 1970—Continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average[c]	Monthly average[b]	12-month average[c]	Monthly average[b]	12-month average[c]
UNITED STATES—Continued								
Minn:	Fergus Falls	P	6	8	0	0	0	13
	Little Falls	P	4	11	0	0	14	23
Miss:	Jackson[d]	P	NA	12	0	0	0	11
Mo:	Kansas City[d]	P	NA	8	0	0	0	2
	St. Louis[d]	P	NA	8	0	0	0	4
Mont:	Helena[d]	P	NA	5	0	0	20	7
Nebr:	Omaha[d]	P	NA	5	0	0	0	1
Nev:	Las Vegas[d]	P	NA	3	0	0	0	0
N.H:	Manchester[d]	P	NA	9	0	0	26	19
N.J:	Trenton[d]	P	NA	8	0	0	14	9
N.Mex:	Albuquerque[d]	P	NA	3	0	0	0	0
N.Y:	Buffalo[d]	P	6	7	0	0	16	10
	New York City[d]	P	NA	10	0	0	17	17
	Syracuse[d]	P	NA	7	0	0	21	10
	Albany	P	7	7	0 (5)	0	(e)0 (5)	(e)0
	Buffalo	P	(e)0	(e)0	0	0	(e)0	(e)0
	Massena	P	8	7	0 (2)	0	25 (2)	20
	Newburg	P	5	7	0 (5)	0	20 (5)	(e)0
	New York City	P	(e)0	9	0	0	(e)0	(e)0
	Syracuse	P	5	4	0 (2)	0	0 (2)	(e)0
N.C:	Charlotte[d]	P	NS	11	NS	0	NS	13
N.Dak:	Minot[d]	P	NA	10	0	0	0	12
Ohio:	Cincinnati[d]	P	NA	7	0	0	0	3
	Cleveland[d]	P	NA	9	0	0	16	11
Okla:	Oklahoma City[d]	P	NA	7	0	0	0	5
	Oklahoma City	P	NS		NS		NS	
	Enid	P	NS		NS		NS	
	Tulsa	P	NS		NS		NS	
	Lawton	P	NS		NS		NS	
	Ardmore	P	NS		NS		NS	
Oreg:	Portland[d]	P	6	6	0	0	11	5
	Baker	P	NA	4	(e)0	(e)0	17	6
	Coos Bay	P	NA	6	(e)0	(e)0	22	12
	Eugene	P	NA	3	(e)0	(e)0	(e)0	3
	Medford	P	NA	3	(e)0	(e)0	(e)0	8
	Portland composite	P	NA	5	(e)0	(e)0	(e)0	8
	Portland local	P	NA	5	(e)0	(e)0	12	7
	Redmond	P	3	4	(e)0	(e)0	(e)0	2
	Tillamook	R	NA	7	(e)0	(e)0	(e)0	16
Pa:	Philadelphia[d]	P	NA	9	0	0	17	7
	Pittsburgh[d]	P	NA	11	0	0	12	13
	Dauphin	P	8	8	0	2	14	11
	Erie	P	NS	11	NS	3	NS	25
	Philadelphia	P	8	8	0	0	15	14
	Pittsburgh	P	11	13	0	1	26	20
R.I:	Providence[d]	P	NA	9	0	0	16	17
S.C:	Charleston[d]	P	9	9	0	1	13	18
S.Dak:	Rapid City[d]	P	NS	7	NS	0	NS	5
Tenn:	Chattanooga[d]	P	NA	10	0	0	11	10
	Memphis[d]	P	NA	9	0	0	0	6
	Chattanooga	P	8	9	0	0	17	14
	Clinton	P	8	12	0	0	15	14
	Knoxville	P	4	7	10 (2)	0	12 (2)	11
	Nashville	P	5	6	0	0	18	10
	Fayetteville	P	10	12	0	0	22	14
Tex:	Austin[d]	P	NA	3	0	0	0	3
	Dallas[d]	P	NA	7	0	0	14	7
	Amarillo	R	NS		NS		NS	
	Corpus Christi	R	NS		NS		NS	
	El Paso	R	NS		NS		NS	
	Fort Worth	R	NS		NS		NS	
	Harlingen	R	NS		NS		NS	
	Houston	R	NS		NS		NS	
	Lubbock	R	NS		NS		NS	
	Midland	R	NS		NS		NS	
	San Antonio	R	NS		NS		NS	
	Texarkana	R	NS		NS		NS	
	Tyler	R	NS		NS		NS	
	Uvalde	R	NS		NS		NS	
	Wichita Falls	R	NS		NS		NS	
Utah:	Salt Lake City[d]	P	5 (2)	4	0 (2)	0	16 (2)	8
Vt:	Burlington[d]	P	NA	8	0	0	19	13
Va:	Norfolk[d]	P	NA	9	0	0	14	8
Wash:	Seattle[d]	P	NA	5	0	0	0	2
	Spokane[d]	P	NA	5	0	0	0	3
	Benton County	R	NS	0	NS	0	NS	5
	Franklin County	R	8	2	0	0	14	6
	Sandpoint, Idaho	R	14	11	0	0	21	21
	Skagit County	R	6	6	0	0	12	9

See footnotes at end of table.

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Table 2. Concentrations of radionuclides in milk for December 1970 and 12-month period, January 1970 through December 1970—Continued

Sampling location	Type of sample[a]	Radionuclide concentration (pCi/liter)					
		Strontium-90		Iodine-131		Cesium-137	
		Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES—Continued							
W.Va.: Charleston[c]	P	NA	8	0	0	11	5
Wis.: Milwaukee[c]	P	NA	6	0	0	19	11
Wyo.: Laramie[c]	P	5 (3)	5	0 (4)	0	6 (4)	1
CANADA:							
Alberta: Calgary	P	6	7	(d)		22	18
Edmonton	P	8	7	(d)		27	20
British Columbia: Vancouver	P	7	9	(d)		27	25
Manitoba: Winnipeg	P	7	7	(d)		21	24
New Brunswick: Fredericton	P	12	12	(d)		23	23
Newfoundland: St. John's	P	10	17	(d)		17	35
Nova Scotia: Halifax	P	15	12	(d)		21	21
Ontario: Ottawa	P	7	6	(d)		16	14
Sault Ste. Marie	P	12	13	(d)		30	32
Thunder Bay	P	12	12	(d)		22	25
Toronto	P	4	9	(d)		15	10
Windsor	P	4	5	(d)		18	11
Quebec: Montreal	P	7	7	(d)		18	18
Quebec	P	9	9	(d)		31	27
Saskatchewan: Regina	P	8	7	(d)		13	14
Saskatoon	P	9	9	(d)		22	15
CENTRAL AND SOUTH AMERICA:							
Colombia: Bogota	P	2	0	0	0	0	0
Chile: Santiago	P	0	0	0	0	0	0
Ecuador: Guayaquil	P	9	0	0	0	0	0
Jamaica: Kingston	P	NS	5	NS	0	NS	76
Venezuela: Caracas	P	3	1	0	0	0	0
Canal Zone: Cristobal[c]	P	NA	1	0	0	14	10
Puerto Rico: San Juan[c]	P	NA	4	0	0	0	7
PMN Network average[f]		7	7	0	0	8	9

[a] P, pasteurized milk.
R, raw milk.

[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a monthly period, the number of samples in the monthly average is given in parentheses.

[c] Pasteurized Milk Network station. All other sampling locations are part of the State or National network.

[d] Radionuclide analysis not routinely performed.

[e] The practical reporting levels for these networks differ from the general ones given in the text. Sampling results for the networks were equal to or less than the following practical reporting levels:

Iodine-131:		Cesium-137:		Strontium-90:	
	Colorado–25 pCi/liter		Colorado–25 pCi/liter		New York–3 pCi/liter
	Michigan–14 pCi/liter		New York–20 pCi/liter		
	Oregon–15 pCi/liter		Oregon–15 pCi/liter		

[f] This entry gives the average radionuclide concentrations for the Pasteurized Milk Network stations denoted by footnote [c].
NA, no analysis.
NS, no sample collected.

monthly average represents a single sample for the sampling station. Strontium-89 and barium-140 data have been omitted from table 2 since levels at the great majority of the stations for December 1970 were below the respective practical reporting levels. The following station average reflects a sample in which strontium-89 was detected: Ark., Little Rock (PMN), 10 pCi/liter; Fla., Tampa (PMN), 8 pCi/liter; Kans., Kansas City (State), 7 pCi/liter; S.C., Charleston (PMN), 8 pCi/liter.

Iodine-131 results are included in the table, even though they were generally below practical reporting levels. Because of the lower values reflected by the radiation protection guidance provided by the Federal Radiation Council, levels in milk for this radionuclide are of particular public health interest. In general, the practical reporting level for iodine-131 is numerically equal to the upper value of Range I (10 pCi/liter) of the FRC radiation protection guide.

Strontium-90 monthly averages ranged from 0 to 14 pCi/liter in the United States for the month of December 1970, and the highest 12-month average was 17 pCi/liter (Del Norte, Calif.) representing 8.5 percent of the Federal Radiation Council radiation protection guide. Cesium-137 monthly averages ranged from 0 to 53 pCi/liter in the United States for December 1970, and the highest 12-month average was 75 pCi/liter (Southeast Florida), representing 2.1 percent of the value determined by using the recommendations given in the Federal Radiation Council reports. Of particular interest are the consistently higher cesium-137 levels that have been observed in Florida (*8*) and Jamaica. Iodine-131 results for individual samples were all below the practical reporting level, with the exception of Central (State) Indiana, 40 pCi/liter. This sample was collected December 4, 1970.

Special milk samples from the PMN were taken at Denver, Colo; Idaho Falls, Idaho; Salt Lake City, Utah; and Laramie, Wyo., because of an unplanned release of radioactive material from an underground nuclear weapons test at the Nevada Test site on December 18, 1970. Fresh fission products were not detected at any of the PMN stations following this event.

Acknowledgement

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Bureau of Radiological Health
Division of Environmental Sanitation
California State Department of Health

Radiation Protection Division
Canadian Department of National
Health and Welfare

Radiological Health Section
Division of Occupational and
Radiological Health
Colorado State Department of Health

Radiological Health Services
Division of Medical Services
Connecticut State Department of Health

Radiological and Occupational Health
Section
Department of Health and
Rehabilitative Services
State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiation Control Section
Environmental Health Division
Kansas State Department of Health

Radiological Health Services
Division of Occupational Health
Michigan Department of Health

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Nuclear Engineering
New York State Department of
Environmental Conservation

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Division of Occupational and Radiological Health
Environmental Health Services
Oklahoma State Department of Health

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Radiation Control Section
Division of Health
Washington State Department of Social and Health Services

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Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs reported in *Radiological Health Data and Reports* are as follows:

Program	Period reported	Issue
California Diet Study	January–June 1970	November 1970
Carbon-14 and Tritium in Total Diet and Milk	January 1969–June 1970	January 1971
Connecticut Standard Diet	July–December 1969	December 1970
Institutional Diet Samples	July–September 1970	February 1971
Strontium-90 in Tri-City Diets	January–December 1969	June 1970

SECTION II. WATER

The Environmental Protection Agency and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (2–4), set the limits for approval of a drinking water supply containing radium-226 and strontium-90 at 3 pCi/liter and 10 pCi/liter, respectively. Limits may be set higher if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities reported in *Radiological Health Data and Reports* are listed below.

Water sampling program	Period reported	Issue
California	July–December 1968	August 1970
Interstate Carrier Drinking Water	1967–1969	December 1970
Kansas	January–December 1969	September 1970
Minnesota	January–June 1969	January 1970
North Carolina	January–December 1967	May 1969
New York	January–June 1969	June 1970
Radiostrontium in Tap Water, HASL	January–June 1970	April 1971
Tritium in Community Water Supplies	1969	December 1970
Tritium in Surface Waters	January–June 1970	November 1970
Washington	July 1968–June 1969	February 1971

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[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

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(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

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Radiostrontium in Tap Water, January-June 1970

Health and Safety Laboratory
U.S. Atomic Energy Commission

The Health and Safety Laboratory has performed analyses for strontium-90 in tap water at New York City since August 1954. Samples of tap water are collected daily so that by the end of the month a composite of at least 100 liters is available for analysis. Cesium-137 determinations were begun in January 1964. The analytical methods used at the laboratory are given in the Health and Safety Laboratory Manual of Standard Procedures (*1*).

Strontium-90 concentration and cesium-137 to strontium-90 ratios in New York City tap water for January through June 1970 are presented in table 1. These results appear graphically in figure 1.

A decreasing trend has been observed in the strontium-90 concentrations since the July 1963 peak. The maximum strontium-90 concentrations observed are below the acceptable limit as set forth in the interstate carrier drinking water standards (*2*).

Table 1. Radiostrontium in New York City tap water January–June 1970

Sampling months (1970)	Strontium-90[a] (pCi/liter)	Cesium-137/ strontium-90
January	0.84	0.05
February	.65	.06
March	.64	.07
April	.67	NA
May	.59	.10
June	.65	.13

[a] Approximately 100 liters per sample.
NA, no analysis.

REFERENCES

(*1*) U.S. ATOMIC ENERGY COMMISSION. Manual of standard procedures, 40:E-38-01-16. Health and Safety Laboratory, U.S. Atomic Energy Commission, 376 Hudson Street, New York, N.Y. 10014.

(*2*) FEDERAL REGISTER RULES AND REGULATIONS. Title 42-Public Health, Chapter 1, Public Health Service, Department of Health, Education and Welfare; Part 72, Interstate Quarantine, Subpart J, Drinking Water Standards 27:2154–2155. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 6, 1962).

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
January–December 1969	July 1970

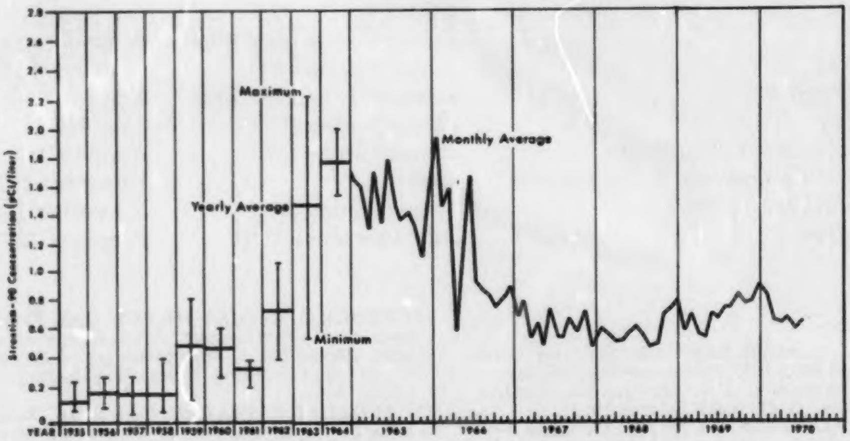

Figure 1. Strontium-90 concentrations in New York City tap water, 1955-June 1970

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[1] Prepared from information appearing in Fallout Program Quarterly Summary Report, HASL 239. This report is available from the National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22151.

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the Environmental Protection Agency, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports:*

Network	Period	Issue
Fallout in the United States and Other Areas, *HASL*	July–December 1968 and January–December 1969	January 1971
Plutonium in Airborne Particulates and Precipitation	January–June 1970	March 1971
Surface Air Sampling Program, 80th Meridian Network, *HASL*	January–December 1967	January 1971

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1. Radiation Alert Network
December 1970

Air Pollution Control Office
Environmental Protection Agency

Surveillance of atmospheric radioactivity the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 70 locations distributed throughout the country (figure 1). Most of the stations are operated by State Health Department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate Environmental Protection Agency officials by mail or telephone depending on levels found. A compilation of the daily field estimates is available upon request from the Data Acquisition and Analysis Branch, Division of Air Quality and Emission Data, EPA, Cincinnati, Ohio. A detailed description of the sampling and analytical procedures was presented in the March 1968 issue of *Radiological Health Data and Reports.*

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique, during December 1970. Time profiles of gross beta radioactivity in air for eight Radiation Alert Network stations are shown in figure 2.

All field estimates reported were within normal limits for the reporting station with the exception of Salt Lake City, Utah, which reported 187 pCi/m³ on December 20, 1970, and 42 pCi/m³ on December 21, 1970, and Boise, Idaho, which reported 27 pCi/m³ on December 21, 1970 and 14 pCi/m³ on December 22, 1970.

These levels were due to an unplanned venting of an underground test at the Nevada Test site near Las Vegas, Nev., on December 18, 1970.

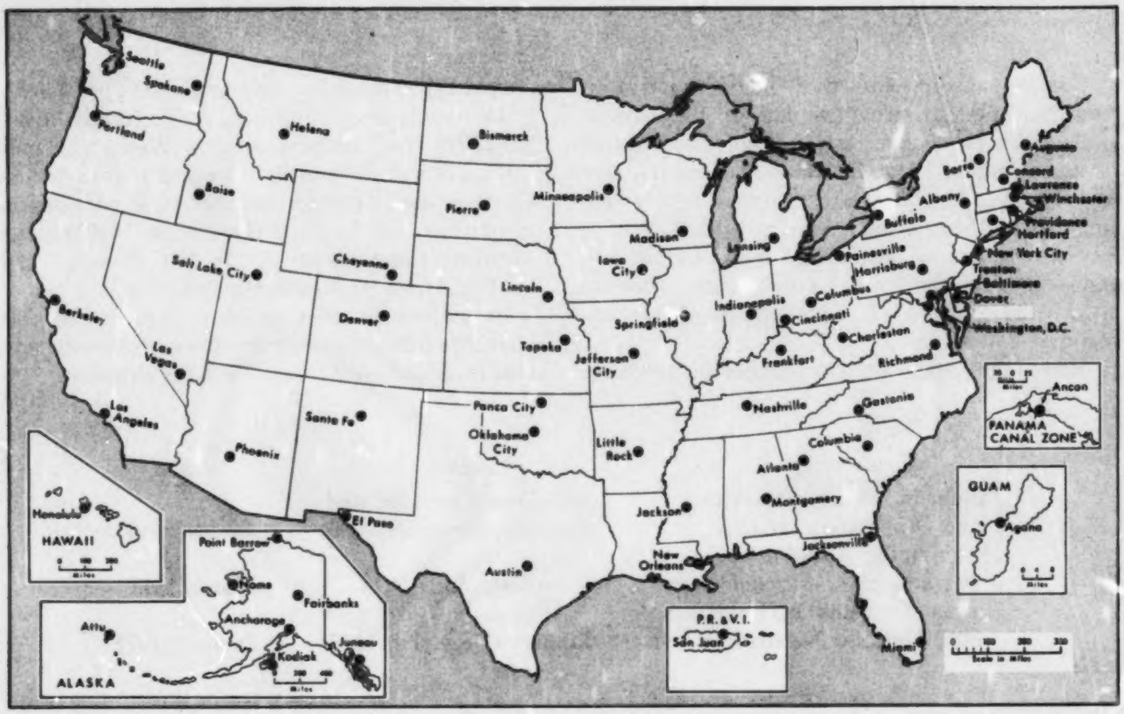
Seattle
Spokane
Portland
Helena
Bismarck
Boise
Pierre
Minneapolis
Salt Lake City
Cheyenne
Lincoln
Denver
Berkeley
Las Vegas
Los Angeles
Phoenix
Santa Fe
Ponca City
Oklahoma City
Topeka
Jefferson City
Little Rock
El Paso
Austin
Madison
Iowa City
Springfield
Lansing
Painesville
Indianapolis
Columbus
Cincinnati
Frankfort
Charleston
Nashville
Atlanta
Montgomery
Columbia
Jackson
New Orleans
Jacksonville
Miami
Gastonia
Richmond
Harrisburg
Buffalo
Albany
Barre
Augusta
Concord
Lawrence
Winchester
Providence
Hartford
New York City
Trenton
Baltimore
Dover
Washington, D.C.
Honolulu
HAWAII
Point Barrow
Nome
Fairbanks
Anchorage
Attu
Kodiak
Juneau
ALASKA
P.R. & V.I.
San Juan
PANAMA CANAL ZONE
Ancon
GUAM
Agana
0 100 200 300
Scale in Miles

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, December 1970

Station location		Number of samples	Air surveillance gross beta radioactivity (5-hour field estimate) (pCi/m³)			Last profile in RHD&R	Precipitation				
							Number of samples	Total depth (mm)	Field estimation of deposition		
		Air	Maximum	Minimum	Average[a]				Number of samples	Depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	22	5	0	1	Oct 70	4	116	4	116	25
Alaska:	Anchorage	0				Feb 71	0				
	Attu Island	31	0	0	0	Nov 70	0				
	Fairbanks	12	0	0	0	Mar 71	2	4	2	4	1
	Juneau	4	[b]23	1	7	Apr 71	4	105	4	105	0
	Kodiak	0				Sept 70	0				
	Nome	0				Dec 70	0				
	Point Barrow	0				Nov 70	0				
Ariz:	Phoenix	12	10	2	5	Aug 70	0				
Ark:	Little Rock	17	3	0	1	Mar 71	0				
Calif:	Berkeley	21	2	0	0	Sept 70	11	156	11	156	1
	Los Angeles	22	4	0	1	Dec 70	0				
C.Z:	Ancon	0				Sept 70	0				
Colo:	Denver	24	7	1	3	Sept 70	0				
Conn:	Hartford	22	1	0	0	Apr 71	7	60	7	60	0
Del:	Dover	20	3	0	1	Feb 71	0				
D.C:	Washington	26	1	0	0	Dec 70	0				
Fla:	Jacksonville	21	2	0	1	Mar 71	5	54	5	54	107
	Miami	11	0	0	0	Apr 71	0				
Ga:	Atlanta	18	2	1	1	Jan 71	1	41	1	41	10
Guam:	Agana	0				Feb 71	0				
Hawaii:	Honolulu	25	0	0	0	Nov 70	7	64	(c)		
Idaho:	Boise	22	27	0	4	Nov 70	9	41	9	41	10
Ill:	Springfield	8	3	0	1	Dec 70	0				
Ind:	Indianapolis	22	2	0	1	Jan 71	0				
Iowa:	Iowa City	20	4	0	1	Sept 70	2	51	2	51	13
Kans:	Topeka	22	6	0	2	Mar 71	3	44	3	44	0
Ky:	Frankfort	0				Dec 70	0				
La:	New Orleans	20	1	0	0	Aug 70	6	81	(c)		
Maine:	Augusta	0				Jan 71	0				
Md:	Baltimore	22	2	0	1	Apr 71	4	28	4	28	0
Mass:	Lawrence	22	0	0	0	Sept 70	4	58	4	58	0
	Winchester	21	1	0	0	Oct 70	6	123	6	123	0
Mich:	Lansing	21	1	0	0	Nov 70	0				
Minn:	Minneapolis	21	2	0	0	Feb 71	3	30	3	30	6
Miss:	Jackson	17	1	0	0	Aug 70	3	53	2	28	0
Mo:	Jefferson City	22	4	0	1	Jan 71	4	47	4	47	0
Mont:	Helena	19	8	0	1	Oct 70	3	12	3	12	0
Nebr:	Lincoln	10	12	1	4	Jan 71	0				
Nev:	Las Vegas	15	4	1	1	Apr 71	0				
N.H:	Concord	0				Dec 70	0				
N.J:	Trenton	20	1	0	0	Aug 70	6	71	6	71	2
N.Mex:	Santa Fe	20	2	0	1	Oct 70	0				
N.Y:	Albany	0				Jan 71	2	22	2	22	12
	Buffalo	19	1	0	0	Sept 70	0				
	New York City	0				Oct 70	0				
N.C:	Gastonia	16	15	1	6	Sept 70	4	42	(c)		
N Dak:	Bismarck	22	1	0	0	Dec 70	3	12	3	12	2
Ohio:	Cincinnati	0				Feb 71	0				
	Columbus	0				Aug 70	0				
	Painesville	17	3	0	1	Apr 71	6	71	6	71	0
Okla:	Oklahoma City	16	7	1	2	Nov 70	0				
	Ponca City	21	11	1	3	Apr 71	2	30	2	30	0
Oreg:	Portland	21	2	0	0	Jan 71	15	219	15	219	18
Pa:	Harrisburg	13	1	0	0	Feb 71	1	10	1	10	1
P.R:	San Juan	0				Aug 70	0				
R.I:	Providence	17	1	0	0	Nov 70	0				
S.C:	Columbia	18	6	0	2	Oct 70	5	96	5	96	6
S. Dak:	Pierre	22	4	0	1	Aug 70	0				
Tenn:	Nashville	19	2	0	1	Nov 70	8	92	8	92	2
Tex:	Austin	0				Feb 71	0				
	El Paso	1	1	1	1	Dec 70	0				
Utah:	Salt Lake City	30	187	0	8	Jan 71	6	48	6	48	4
Vt:	Barre	19	1	0	0	Mar 71	9	96	9	96	13
Va:	Richmond	22	1	0	0	Mar 71	3	55	3	55	54
Wash:	Seattle	12	1	0	0	Mar 71	7	89	(c)		
	Spokane	15	3	0	1	Feb 71	0				
W. Va:	Charleston	22	2	0	1	Oct 70	9	75	9	75	11
Wisc:	Madison	22	2	0	0	Mar 71	7	17	6	16	2
Wyo:	Cheyenne	22	4	1	1	Apr 71	2	6	2	6	0
Network summary		1,038	187	0	1		183	69	5	60	9

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.
[b] These data are suspect.
[c] This station is part of the plutonium in precipitation network. No gross beta measurements are done.

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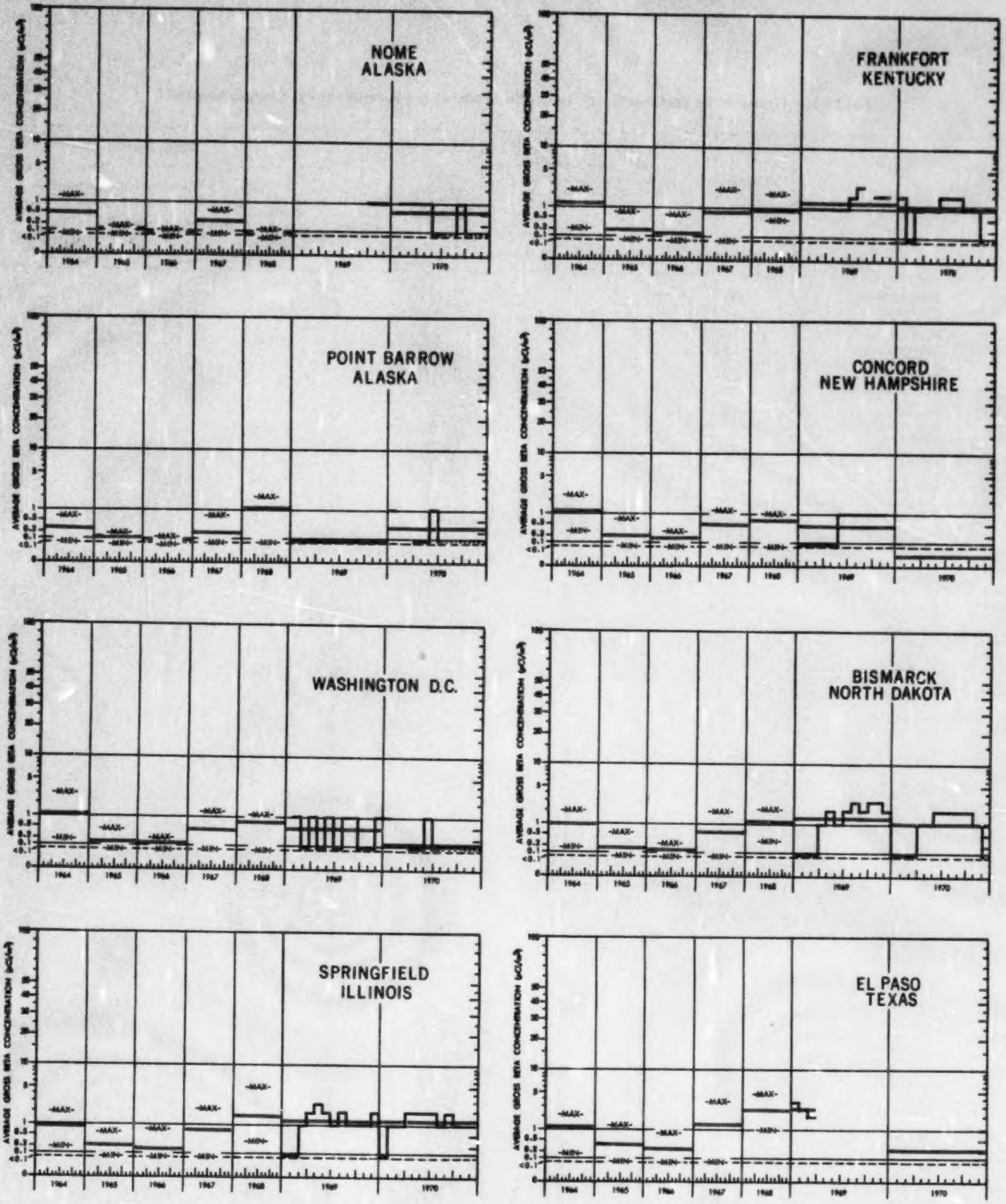

Figure 2. Monthly and yearly profiles of beta radioactivity in air—Radiation Alert Network, 1964–December 1970

2. Canadian Air and Precipitation Monitoring Program[1], December 1970

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports.*

Surface air and precipitation data for December 1970 are presented in table 2.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, December 1970

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	4	0.1	0.0	0.1	31	0.30
Coral Harbour	4	.1	.0	.1	47	.23
Edmonton	4	.1	.1	.1	160	.34
Ft. Churchill	4	.1	.1	.1	24	.24
Fredericton	2	.1	.0	.1	8	1.24
Goose Bay	4	.1	.0	.1	5	.37
Halifax	4	.1	.1	.1	7	1.43
Inuvik	3	.1	.0	.1	23	.41
Montreal	4	.1	.0	.0	5	.50
Moosonee	4	.1	.1	.1	48	1.77
Ottawa	2	.2	.0	.1	14	1.11
Quebec	4	.1	.1	.1	8	.35
Regina	10	.3	.1	.1	17	.31
Resolute	1	.1	.1	.1	203	.20
St. John's, Nfld	2	.0	.0	.0	NS	NS
Saskatoon	10	.2	.1	.1	1	.03
Sault Ste. Marie	10	.2	.1	.1	18	1.02
Thunder Bay	10	.2	.0	.1	12	.75
Toronto	10	.7	.0	.2	21	1.70
Vancouver	4	.0	.0	.0	2	.37
Whitehorse	4	.1	.0	.1	14	.25
Windsor	10	.6	.0	.3	4	.18
Winnipeg	10	.2	.1	.1	17	.41
Yellowknife	3	.1	.1	.1	22	.39
Network summary	127	0.7	0.0	0.1	31	0.60

NS, no sample.

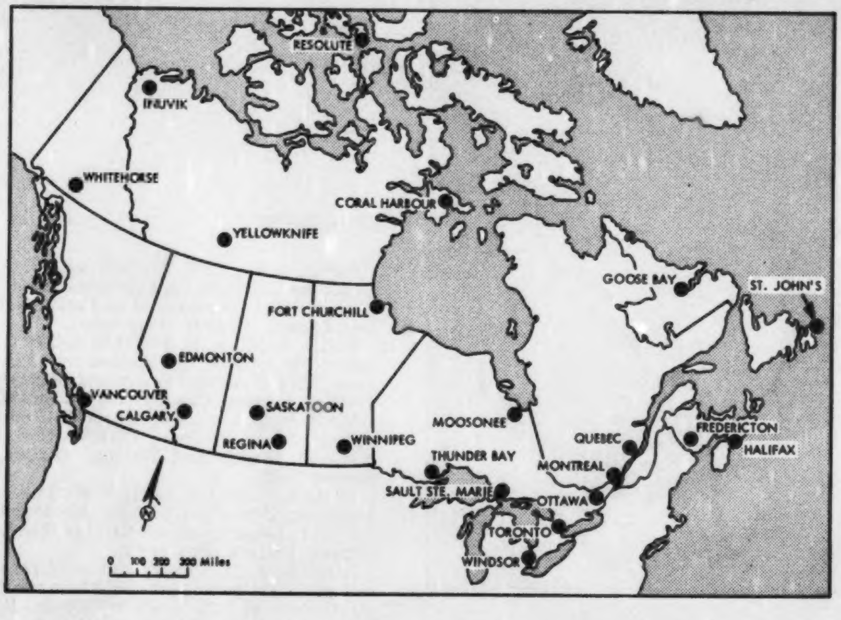
RESOLUTE
INUVIK
WHITEHORSE
CORAL HARBOUR
YELLOWKNIFE
GOOSE BAY
ST. JOHN'S
FORT CHURCHILL
EDMONTON
VANCOUVER
CALGARY
SASKATOON
REGINA
WINNIPEG
MOOSONEE
QUEBEC
FREDERICTON
HALIFAX
THUNDER BAY
MONTREAL
SAULT STE. MARIE
OTTAWA
TORONTO
WINDSOR
0 100 200 300 Miles

Figure 3. Canadian air and precipitation sampling stations

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[1] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

3. Pan American Air Sampling Program December 1970

Pan American Health Organization and *Environmental Protection Agency*

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the Environmental Protection Agency (EPA) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 4. Analytical techniques were described in the March 1968 issue of *Radiological Health Data and Reports*. The December 1970 air monitoring results from the participating countries are given in table 3.

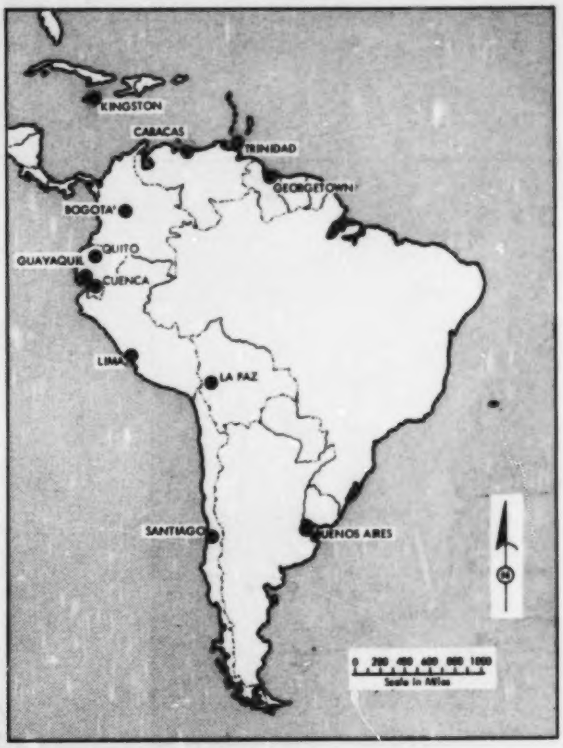

Figure 4. Pan American Air Sampling Program Stations

Table 3. Summary of gross beta radioactivity in Pan American surface air, December 1970

Station location	Number of samples	Gross beta radioactivity (pCi/m^3)		
		Maximum	Minimum	Average[a]
Argentina: Buenos Aires	NS			
Bolivia: La Paz	12	0.31	0.00	0.10
Chile: Santiago	19	.38	.05	.18
Colombia: Bogota	21	.06	.00	.03
Ecuador: Cuenca	NS			
Guayaquil	NS			
Quito	NS			
Guyana: Georgetown	9	.06	.01	.03
Jamaica: Kingston	NS			
Peru: Lima	25	.40	.03	.25
Venezuela: Caracas	6	.07	.01	.03
West Indies: Trinidad	11	.13	.00	.06
Pan American summary	103	0.40	0.00	0.12

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m^3 are reported and used in averaging as 0.00 pCi/m^3.

NS, no sample.

REFERENCES

(*1*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1959 on the Radioactive Fallout Study Program, CNHW-RP-3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(*2*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW-RP-4. Department of National Health and Welfare, Ottawa, Canada (December 1961).

(*3*) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW-RP-5. Department of National Health and Welfare, Ottawa, Canada (December 1962).

(*4*) BEALE, J. and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD-11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(*5*) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD-21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

Surface Air Sampling Program-80th Meridian Network January-December 1968

Health and Safety Laboratory
Atomic Energy Commission

The Health and Safety Laboratory began its Surface Air Sampling Program in January 1963, as a continuation of the 80th Meridian Program conducted by the U.S. Naval Research Laboratory. The objectives of this program are to determine the concentrations of radioactivity in surface air in both hemispheres as a function of latitude and season and to interpret these data in terms of the dominant meteorological and physical processes which are operative.

The basic network consists of a line of sites approximately along the 80th Meridian extending from about 76° N to 90° S latitudes (figure 1). Since 1963, a number of sites have been added to investigate the possible effects of longitude, elevation, and proximity to coastlines; and in late 1965, samplers were placed on four Atlantic Ocean weather ships to extend the surface air study over the marine environment. The Environmental Science Services Administration, Department of Commerce, maintains a collection site at the Amundson Scott Station in Antarctica. The air filter samples from this site are also included in the HASL program.

Sampling and analytical procedures

Approximately 1,400 cubic meters of ambient air per day are drawn through an 8-inch diameter microsorban filter for the land stations. For the ocean stations, about 2,200 cubic meters of air per day are filtered by an 8- by 10-inch microsorban filter. Each filter is changed on the 1st, 8th, 15th, and 22nd of the month or more frequently if the filter becomes clogged with debris suspended in the air. Under normal conditions, the filters from each station are compressed into a monthly composite, and the gamma spectrum of the composite is obtained by analysis with an 8- by 4-inch NaI (Tl) crystal approximately 2 weeks after the last collection in the month.

The integrated response between 100 keV and and 3.0 MeV is corrected by the average detection efficiency (35 percent) of the gamma photons present in fallout, and the total gamma radioactivity is reported in units of photons/min/1,000 m^3. Average monthly gamma concentrations are calculated by weighting the concentrations in each sampling interval by the relative period of time in the interval. After the gamma measurements have been completed, monthly composites from each site are submitted to contractor laboratories for radiochemical analyses.

Since the last major nuclear weapon test series occurred at the end of 1962, only the longer lived, artifically produced radionuclides were present in the filters analyzed prior to May 1966. Consequently, emphasis was given to the determination of manganese-54, iron-55, strontium-90, cadmium-109, cesium-137, cerium-144, plutonium-238, and plutonium-239. Strontium-89, zirconium-95 and cerium-141 were analyzed in samples collected after the foreign nuclear test of May 1966.

The longer lived fission products and plutonium-239 concentrations should describe the general distribution in surface air of all previous nuclear weapon debris which was transferred from the lower stratosphere to the troposphere during the collection period of this report. Other tracer radionuclides can be associated with debris from a single detonation or a series of detonations.

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[1] Summarized from "Fallout Program Quarterly Summary Report," HASL 224,239 available from the National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22151.

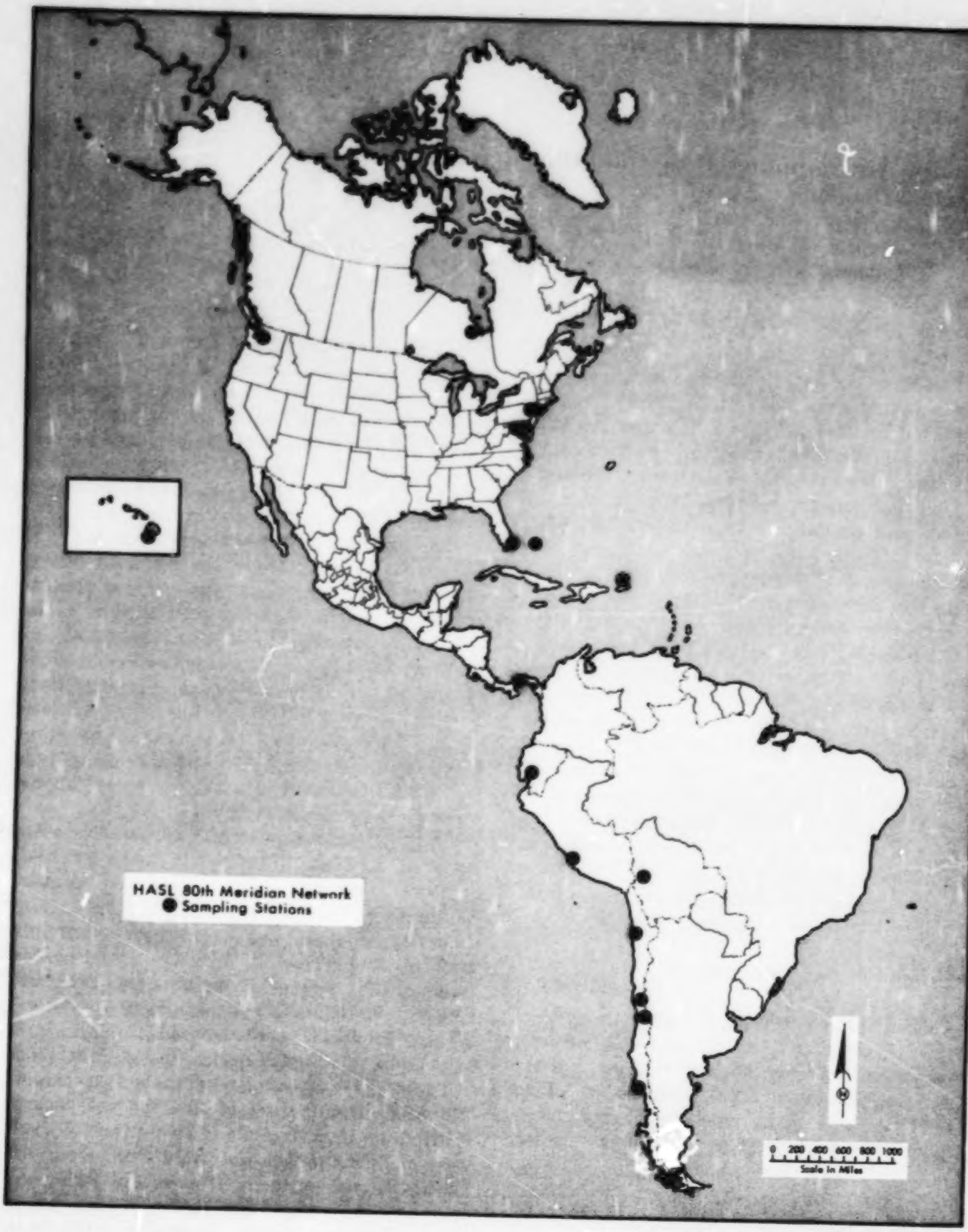
HASL 80th Meridian Network
Sampling Stations
0 200 400 600 800 1000
Scale in Miles

Figure 1. 80th Meridian Network sampling stations

Manganese-54 and iron-55 were produced in large quantities in the 1961 and 1962 test series. Cadmium-109 was generated by the U.S. high altitude test over Johnston Island on July 9, 1962. While plutonium-238 is present in low concentrations in nuclear weapons debris, about 17,000 curies of plutonium-238 was disseminated at high altitude in the stratosphere on April 21, 1964 during the reentry burnup of a SNAP-9A power source. As the levels of any of the radionuclides drop to below practical determination limits, they are eliminated from the radiochemical program; thus cadmium-109 was not analyzed after the end of 1967.

During 1968, Tracerlab, Incorporated, of Richmond, Calif. (now known as Trapelo Division/West) performed the analyses of most of the samples in this program.

Results

The radioactivity concentrations in surface air during January–December 1968 are presented in tables 2 through 9. The sites are listed according to latitude beginning with the most northern site at Thule, Greenland (table 1). The results of the blank and standard analyses are reported in tables 10 and 11.

The concentrations are reported at the midpoint of the collection month for the plutonium isotopes and the fission products and on October 15, 1961 for the induced radionuclide, iron-55.

Table 1. Station location

Site		Latitude	Longitude (west)	Elevation (meters)
Greenland:	Thule	76° 36′ N	68° 35′	250
Ocean station:	Bravo	56° 30′ N	51° 00′	0
	Charlie	52° 45′ N	35° 30′	0
Ontario:	Moosonee	51° 16′ N	80° 30′	10
Wash:	Seattle	47° 36′ N	122° 22′	3
Ocean station:	Delta	44° 00′ N	41° 00′	0
N.J:	Westwood	41° 00′ N	74° 01′	38
N.Y:	New York City	40° 48′ N	73° 58′	38
Va:	Sterling	38° 58′ N	77° 25′	76
Ocean station:	Echo	35° 00′ N	48° 00′	0
Fla:	Miami	25° 49′ N	80° 17′	4
Bahamas:	Bimini	25° 46′ N	79° 22′	3
Hawaii:	Mauna Loa	19° 28′ N	155° 36′	3.401
P.R:	San Juan	18° 26′ N	66° 00′	10
Panama:	Balboa	8° 58′ N	79° 34′	23
Ecuador:	Guayaquil	2° 10′ S	79° 52′	7
Peru:	Lima	12° 01′ S	77° 08′	13
Bolivia:	Chacaltaya	16° 21′ S	68° 07′	5.220
Chile:	Antofagasta	23° 37′ S	70° 16′	31
	Isle de Pasqua-Easter Isle	27° 10′ S	109° 26′	41
	Portillo	32° 50′ S	70° 08′	2.850
	Santiago	33° 27′ S	70° 42′	520
	Puerto Montt	41° 27′ S	72° 57′	7
	Punta Arenas	53° 08′ S	70° 53′	35

Table 2. Iron-55 concentrations in surface air, January–December 1968[a]

Site		Concentration[b] (dpm/1,000 standard m³ at midmonth)					
		Jan	Feb	Mar	Apr	May	June
Greenland:	Thule	31.63	33.17	39.27	27.93	32.00	—
Ocean station:	Bravo	13.95	[c]7.32	28.66	34.14	16.82	12.12
	Charlie	19.25	45.15	34.78	16.83	30.04	30.63
Ontario:	Moosonee	15.70	26.42	43.95	37.66	69.18	77.00
Ocean station:	Delta	20.30	—	32.08	54.83	47.60	38.69
N.Y:	New York City	39.10	36.11	50.28	52.62	87.38	86.81
Va:	Sterling	38.08	[c]32.10	69.60	104.24	65.03	79.84
Ocean station:	Echo	20.27	—	25.24	61.88	52.03	51.05
Fla:	Miami	52.49	60.77	105.57	78.82	51.53	29.82
Bahamas:	Bimini	77.20	68.45	120.66	187.07	56.38	—
Hawaii:	Mauna Loa	36.20	18.42	61.06	109.03	66.07	78.72
P.R:	San Juan	20.67	[c]22.66	59.80	71.07	40.32	55.46
Panama:	Balboa	[c]14.96	19.03	41.81	87.30	[c]6.99	[c]13.10
Ecuador:	Guayaquil	(d)	(d)	[b]4.70	(d)	(d)	[c]10.21
Peru:	Lima	[c]19.50	(d)	[c]16.55	(d)	(d)	[c]26.52
Bolivia:	Chacaltaya	(d)	(d)	[c]5.33	(d)	[c]5.47	[c]11.25
Chile:	Antofagasta	[c]16.96	(d)	(d)	(d)	(d)	[c]16.11
	Isle de Pasqua-Easter Isle	—	[c]29.85	—	(d)	—	—
	Santiago	[c]46.94	(d)	[c]59.73	(d)	[c]40.86	—
	Puerto Montt	(d)	[c]6.57	[b]6.90	(d)	(d)	[c]7.00
	Punta Arenas	(d)	(d)	(d)	[c]10.71	(d)	—

[a] No data reported for July–December 1968.

[b] Errors are less than 20 percent except:

[c] error between 20-100 percent.

[d] error greater than 100 percent.

—, no data reported.

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One standard deviation of the counting error for these data is always less than ±20 percent unless otherwise indicated.

Table 3. Strontium-89 concentrations in surface air January–December 1968[a]

Site		Concentration[b] (dpm/1,000 standard m³ at midmonth)		
		Jan	July	Aug
Greenland:	Thule	17.30	4.76	(c)1.17
Ocean station:	Bravo	7.97	(c).66	5.13
	Charlie	24.60	4.35	—
Ontario:	Moosonee	12.50	(c)8.47	(c)2.96
Ocean station:	Delta	—	—	(c)1.00
N.Y:	New York City	26.42	—	2.07
Va:	Sterling	—	6.96	4.22
Ocean station:	Echo	36.97	—	(c)3.83
Fla:	Miami	88.31	—	9.60
Bahamas:	Bimini	124.87	—	9.93
Hawaii:	Mauna Loa	253.12	—	13.24
P.R:	San Juan	70.47	—	18.87
Panama:	Balboa	51.78	—	71.47
Ecuador:	Guayaquil	2.42	11.65	277.51
Peru:	Lima	(c).80	—	899.06
Bolivia:	Chacaltaya	(c).35	—	2,153.61
Chile:	Antofagasta	(c)1.16	—	625.30
	Portillo	(c)—	525.49	2,504.03
	Santiago	(c)1.73	—	408.10
	Puerto Montt	(c)1.31	2.33	103.02
	Punta Arenas	(c).47	(d)	20.29

[a] No data reported from February through June and September through December 1968.
[b] Errors are less than 20 percent except:
[c] Error between 20–100 percent
[d] Error greater than 100 percent
—, no data reported.

Three quality control samples are submitted along with each monthly shipment of samples for analysis. A weighed aliquot of a standard solution of a nuclide to be analyzed is added to two of these filters, and the third filter serves as a blank. The pattern of additions is varied for each nuclide so that different filters are blanks for different nuclides.

All the values reported by the contractor are corrected for a reagent blank, so that the blank values reported here reflect the contamination of the filter material both during manufacture and during handling at HASL and at the contractor laboratory.

Table 10 lists the results of the analyses of the blanks for each nuclide. In general, these data indicate low levels of contamination for most of the nuclides, however, it is significant to note that the average plutonium-238 blank rose from 0.04 dpm in 1967 to 0.22 dpm in 1968. Because the amount of plutonium-238 found in surface air samples is frequently in the range of 1 dpm, this blank may represent a significant fraction of the total radioactivity.

The results of analyses on standard samples are shown in table 11. These data are indicative

Table 4. Strontium-90 concentrations in surface air, January–December 1968

Site		Concentration[a] (dpm/1,000 standard m³ at midmonth)											
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Greenland:	Thule	2.61	4.04	6.07	4.53	4.33	3.92	3.13	5.30	4.11	1.80	2.22	—
Ocean station:	Bravo	1.00	1.22	3.50	4.14	3.08	2.85	1.90	1.80	1.68	1.50	1.13	1.12
	Charlie	1.74	2.64	3.26	3.19	4.06	3.39	2.38	—	2.35	1.10	1.52	.57
Ontario:	Moosonee	1.77	2.91	6.23	7.84	9.01	9.32	6.00	5.56	4.83	—	1.07	1.82
Ocean station:	Delta	2.25	—	4.79	7.00	5.56	5.14	4.52	4.81	2.61	2.13	—	1.80
N.Y:	New York City	3.16	4.53	7.53	9.95	11.00	6.87	8.23	6.22	6.08	2.92	1.94	2.49
Va:	Sterling	—	4.99	7.54	10.85	9.15	10.11	9.12	5.29	5.26	3.78	2.43	2.70
Ocean station:	Echo	2.28	—	3.83	7.66	7.29	6.27	5.92	4.95	2.13	3.78	2.06	2.55
Fla:	Miami	3.46	5.90	13.17	14.85	4.72	3.06	4.19	3.90	2.30	2.97	3.62	3.23
Bahamas:	Bimni	4.77	7.18	9.12	11.95	5.66	2.84	3.81	5.12	1.53	8.33	—	—
Hawaii:	Mauna Loa	5.16	2.77	7.45	13.68	10.30	11.66	6.20	5.36	4.07	2.16	1.33	2.61
P.R:	San Juan	2.64	3.42	9.31	14.39	5.78	4.96	5.86	4.23	2.93	3.16	1.17	2.15
Panama:	Balboa	2.22	2.16	5.80	9.87	1.08	.37	2.02	1.83	.63	.32	[b].52	1.00
Ecuador:	Guayaquil	.68	.72	.53	.43	.42	.39	.35	2.58	2.30	1.04	.66	3.27
Peru:	Lima	1.61	1.53	1.17	.83	.51	.50	1.14	8.85	6.83	4.15	6.67	4.26
Bolivie:	Chacaltaya	.35	[b].16	[b].83	.51	.53	0.81	[b]7.62	19.28	12.73	3.97	4.49	4.43
Chile:	Antofagasta	2.00	1.40	1.52	.73	.93	1.32	2.27	6.47	5.56	3.56	4.71	3.17
	Isle de Pasqua-Easter Isle	1.73	1.70	—	1.26	—	—	—	—	—	—	—	—
	Portillo	—	—	—	—	—	—	6.51	24.84	2.37	—	—	—
	Santiago	2.81	2.00	2.07	.89	.96	1.00	1.29	3.48	4.06	2.05	5.52	3.43
	Puerto Montt	1.81	1.25	1.12	.82	(b).52	.53	.54	1.72	1.74	1.22	1.74	2.20
	Punta Arenas	.83	.90	.95	.82	.42	.33	(b).52	.53	.75	.56	.68	.80

[a] Errors are less than 20 percent except:
[b] Error between 20–100 percent.
[c] Error greater than 100 percent.
—, no data reported.

Table 5. Zirconium-95 concentrations in surface air, January–December 1968

Site		Concentration[a] (dpm/1,000 standard m³ at midmonth)											
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Greenland:	Thule	76.01	60.34	50.64	31.46	19.78	13.51	12.18	9.77	5.20	2.30	2.50	—
Ocean station:	Bravo	23.25	16.04	29.61	25.30	16.51	10.12	4.48	3.30	—	1.92	1.59	.95
	Charlie	46.89	37.73	34.06	22.73	20.32	11.03	6.18	—	3.28	1.83	1.72	.81
Ontario:	Moosonee	25.72	33.83	57.17	47.53	41.65	30.99	17.97	10.59	9.07	—	—	1.77
Ocean station:	Delta	89.35	—	39.62	47.14	28.75	17.16	13.95	8.65	4.54	3.19	—	—
N.Y:	New York City	85.11	70.15	77.53	66.49	51.16	34.36	25.03	13.35	37.42	—	—	2.70
Va:	Sterling	78.72	68.17	72.36	63.13	44.04	33.95	23.12	13.24	13.51	6.43	—	3.59
Ocean station:	Echo	54.68	—	—	50.09	32.74	22.85	15.03	10.45	—	—	4.56	3.46
Fla:	Miami	112.44	95.64	131.98	103.22	33.93	—	10.74	26.05	24.31	16.11	—	—
Bahamas:	Bimini	146.37	118.87	143.53	114.78	34.95	[b] .68	16.57	30.58	26.80	34.75	—	—
Hawaii:	Mauna Loa	155.49	31.27	58.26	83.28	39.64	32.84	16.20	28.31	50.17	31.18	—	10.43
P.R:	San Juan	48.70	37.82	90.93	84.04	27.96	—	18.45	29.28	33.54	—	—	5.74
Panama:	Balboa	48.49	34.05	54.16	65.08	5.01	[b] 1.52	7.62	77.45	—	13.25	—	6.08
Ecuador:	Guayaquil	3.93	3.21	[b] 3.74	[b] 2.78	1.13	[b] .49	21.67	476.08	205.16	—	—	145.70
Peru:	Lima	4.02	1.91	24.50	(b)	[b] .76	[b] .67	60.68	1,025.82	596.98	355.72	—	178.46
Bolivia:	Chacaltaya	[b] .57	[b] .49	(b)	[b] .91	[b] .78	[b] 1.36	1,396.15	3,343.37	1,534.69	—	267.69	181.57
Chile:	Antofagasta	5.94	[b] 1.84	[b] 1.98	(c)	[b] .62	[b] .57	175.47	895.38	434.24	256.79	—	156.34
	Isle de Pasqua-Easter Isle	—	[b] 1.04	—	[b] .55	—	—	—	—	—	—	—	—
	Portillo	—	—	—	—	—	—	619.61	3,096.78	55.93	—	—	—
	Santiago	6.60	[b] 2.03	[b] 1.00	(b)	[b] .54	—	137.64	579.44	317.56	—	151.40	119.33
	Puerto Montt	4.37	1.45	.52	.39	(b)	(b)	6.12	125.52	98.48	—	91.38	—
	Punta Arenas	2.04	(b) .85	[b] .53	[b] .37	(b)	(b)	(b)	27.40	—	—	23.86	23.34

[a] Errors are less than 20 percent except:
[b] error between 20–100 percent
[c] error greater than 100 percent
—, no data reported.

of the accuracy of the radiochemical analyses. The values shown are the average percent deviations between the added activities and the results reported by the contractor. Although most of the results are satisfactory, there appears to be a large positive bias in the plutonium-238 values for much of 1968, which cannot be accounted for by the increase of the blank contamination.

Table 6. Cesium-137 and cerium-141 concentrations in surface air during 1968[a]

Site		Concentration[b] (dpm/1,000 standard m³ at midmonth)						
		Cesium-137						Cerium-141[a]
		July	Aug.	Sept	Oct.	Nov	Dec	Jan
Greenland:	Thule	7.66	8.32	6.44	3.23	4.36	—	67.73
Ocean station:	Bravo	2.86	2.93	2.51	2.40	1.72	1.52	40.81
	Charlie	3.68	—	4.25	1.55	2.29	.87	53.57
Ontario:	Moosonee	11.39	10.12	8.37	—	2.58	2.71	[c] 13.44
Ocean station:	Delta	6.89	6.94	3.67	1.94	—	2.89	—
N.Y:	New York City	18.30	12.48	10.42	6.74	4.36	4.80	53.90
Va:	Sterling	12.62	9.17	8.66	4.88	4.67	4.39	[c] 88.30
Ocean station:	Echo	9.84	7.83	3.11	6.19	3.38	4.12	55.88
Fla:	Miami	8.24	8.01	3.40	3.02	6.94	8.27	261.19
Bahamas:	Bimini	9.49	10.92	3.05	18.00	—	—	295.34
Hawaii:	Mauna Loa	10.30	8.96	6.26	3.38	1.84	3.90	314.54
P.R:	San Juan	9.05	8.49	4.65	5.28	1.95	3.47	[c] 71.76
Panama:	Balboa	3.80	2.71	.89	[c] .09	.71	1.64	[c] 100.82
Ecuador:	Guayaquil	.67	4.95	3.39	2.57	3.84	5.60	[c] 8.21
Peru:	Lima	2.00	11.92	8.26	3.71	8.90	6.30	(d)
Bolivia:	Chacaltaya	10.46	28.04	17.43	6.78	6.09	6.08	(c) 13.64
Chile:	Antofagasta	3.60	10.66	7.93	(d)	7.11	6.32	(d)
	Portillo	9.41	36.94	3.09	—	—	—	—
	Santiago	2.93	9.10	7.37	4.85	7.83	6.17	[c] 21.73
	Puerto Montt	.82	2.24	2.28	1.63	2.46	3.00	[c] 6.83
	Punta Arenas	.58	.71	1.21	.80	.87	1.09	(d)

[a] Cesium-137, no data reported for January–June 1968
Cerium-141 no data reported for February–December 1968.
[b] Errors are less than 20 percent except:
[c] error between 20–100 percent.
[d] error greater than 100 percent.
—, no data reported.

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Table 7. Cerium-144 concentrations in surface air, January–December 1968

Site		Concentration[a] (dpm/1,000 standard m³ at midmonth)											
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Greenland:	Thule	39.28	60.58	82.19	76.06	66.89	62.19	65.31	46.36	45.05	23.65	25.51	—
Ocean station:	Bravo	12.93	16.34	51.34	69.68	52.65	45.08	26.13	25.32	21.32	18.08	11.93	8.90
	Charlie	30.28	38.94	56.81	96.19	74.56	47.87	32.96	—	27.59	14.37	14.42	6.21
Ontario:	Moosonee	17.33	36.30	100.22	123.38	157.65	159.32	105.74	74.23	61.50	—	15.93	15.49
Ocean station:	Delta	38.27	—	76.20	122.26	102.88	77.39	65.60	62.11	30.89	24.96	—	18.57
N.Y:	New York City	47.31	72.79	127.28	185.50	194.68	181.29	152.45	81.11	65.30	40.91	27.05	24.36
Va:	Sterling	46.28	75.86	124.62	185.94	159.84	153.58	128.31	78.61	60.75	38.05	27.94	26.32
Ocean station:	Echo	28.79	—	71.73	140.34	124.47	105.67	85.37	66.37	[b]23.90	47.93	23.30	34.30
Fla:	Miami	69.40	115.90	242.13	278.82	134.18	53.98	75.19	65.26	33.50	78.55	46.08	48.37
Bahamas:	Bimini	91.71	140.00	266.39	348.28	131.12	51.77	81.33	92.88	27.42	111.48	—	—
Hawaii:	Mauna Loa	85.46	47.78	120.25	249.83	176.07	166.55	85.33	64.30	55.89	179.86	16.82	25.83
P.R:	San Juan	47.15	44.82	168.13	236.91	101.61	76.75	82.76	71.50	41.14	40.56	13.12	21.98
Panama:	Balboa	26.44	40.21	104.53	157.41	16.97	6.34	33.25	33.42	15.28	6.24	6.85	11.58
Ecuador:	Guayaquil	4.00	3.64	6.59	6.96	4.51	1.80	5.62	128.95	—	52.62	73.28	98.53
Peru:	Lima	5.48	2.95	2.55	1.73	2.78	2.49	17.82	288.73	189.42	20.82	175.67	117.91
Bolivia:	Chacaltaya	[b].44	.71	.84	2.55	2.39	5.73	270.38	756.02	436.73	153.93	118.77	110.20
Chile:	Antofagasta	7.70	3.51	2.34	1.72	2.89	2.82	39.75	255.47	148.48	105.43	124.69	102.93
	Santiago	11.43	4.60	3.09	1.53	2.65	1.83	37.07	166.36	120.99	82.27	121.50	98.00
	Puerto Montt	6.02	2.93	1.37	1.07	.62	.64	1.81	33.18	31.31	24.53	45.17	43.54
	Punta Arenas	3.24	1.81	1.31	.82	.56	.60	—	7.28	12.28	9.73	12.03	15.64

[a] Errors are less than 20 percent except:
[b] error between 20–100 percent.
—, no data reported.

Table 8. Plutonium-238 concentrations in surface air, January–December 1968

Site		Concentration[a] (dpm/1,000 standard m³ at midmonth)											
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Greenland:	Thule	3.18	3.46	3.84	2.42	1.65	2.25	1.91	1.95	1.77	1.43	1.18	—
Ocean station:	Bravo	2.26	—	[b]2.50	2.77	1.88	3.59	1.33	.95	2.91	1.02	[b]1.14	[b].43
	Charlie	1.69	2.08	2.22	2.04	2.58	2.72	2.66	—	1.48	.92	1.20	[b].56
Ontario:	Moosonee	1.93	2.86	4.62	4.60	5.69	[b]4.07	3.56	3.85	3.75	—	6.75	[b].97
Ocean station:	Delta	1.91	—	7.37	4.37	2.78	2.37	—	2.11	1.45	1.75	—	1.18
N.Y:	New York City	5.47	4.83	7.94	7.49	—	32.21	19.98	8.68	6.98	4.10	2.21	4.02
Va:	Sterling	3.91	[b]5.97	[b]6.86	6.13	5.36	[b]3.40	3.90	2.38	3.13	1.64	1.46	4.55
Ocean station:	Echo	[b]1.51	—	28.43	4.84	[b]3.10	3.65	—	3.26	2.26	2.34	1.43	1.56
Fla:	Miami	3.48	[b]3.10	10.44	7.72	4.03	1.75	2.44	2.48	.90	1.62	2.36	2.51
Bahamas:	Bimini	5.52	5.86	10.74	11.11	4.08	[b]1.35	3.12	3.63	.73	6.33	—	—
Hawaii:	Mauna Loa	[b]3.12	—	4.30	7.09	5.29	5.41	2.65	2.52	3.35	1.65	[b].48	1.62
P.R:	San Juan	2.77	3.17	[b]4.40	6.78	5.75	2.78	3.13	[b]2.03	2.47	[b]2.97	(c)	1.16
Panama:	Balboa	2.37	2.06	3.05	6.06	[b].85	[b].35	1.23	.82	[b].41	[b].21	(c)	.76
Ecuador:	Guayaquil	4.72	4.20	[b]1.69	[b]1.50	2.63	5.55	1.91	[b]1.56	[b]2.45	3.05	2.49	3.29
Peru:	Lima	6.70	7.10	[b]4.55	4.66	2.33	2.75	3.91	4.06	[b]4.84	5.20	6.83	6.33
Bolivia:	Chacaltaya	3.68	[b].53	2.15	3.01	2.08	2.77	3.03	4.94	8.61	3.18	3.66	3.70
Chile	Antofagasta	10.67	[b]7.04	7.39	4.18	3.88	4.31	5.40	5.91	5.58	5.33	6.43	6.68
	Isle de Pasqua-Easter Island	6.67	[b].58	—	5.38	—	—	—	—	—	—	—	—
	Portillo	—	—	—	—	—	—	13.37	23.55	[b]2.45	—	—	—
	Santiago	17.62	11.26	10.58	—	5.52	4.52	5.09	9.28	8.89	6.16	[b]6.88	6.13
	Puerto Montt	8.02	6.22	4.41	3.68	1.72	2.47	1.98	2.95	3.36	[b]2.32	3.11	3.40
	Punta Arenas	3.55	3.65	4.50	3.87	1.42	1.33	[b]1.83	1.46	1.78	1.42	1.33	[b]1.96

[a] Errors are less than 20 percent except:
[b] error between 20–100 percent
[c] error greater than 100 percent
—, no data reported.

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Table 9. Plutonium-239 concentrations in surface air, January–December 1968

Site	Concentration[a] (dpm/1,000 standard m^3 at midmonth)											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Greenland: Thule	—	10.05	11.87	9.79	9.40	15.06	10.17	13.30	10.05	5.77	6.17	—
Ocean station: Bravo	—	—	7.64	9.68	7.59	114.32	4.60	4.55	4.56	4.30	2.77	2.76
Charlie	—	4.76	7.61	8.39	20.14	13.14	4.57	—	6.16	3.15	4.33	1.75
Ontario: Moosonee	—	7.56	14.48	16.34	23.36	28.81	17.39	14.14	12.53	—	4.16	4.67
Ocean station: Delta	4.68	—	13.02	17.02	13.74	14.06	11.13	11.61	8.24	6.11	—	4.07
N.Y: New York City	—	9.58	18.99	27.29	31.43	27.24	30.18	20.13	16.43	10.06	7.70	8.02
Va: Sterling	—	8.78	21.88	24.51	21.84	22.04	25.40	14.40	15.31	9.31	7.44	6.50
Ocean station: Echo	—	—	11.23	17.95	17.67	17.50	16.22	28.36	77.07	18.22	5.83	7.18
Fla: Miami	—	16.62	34.87	30.68	16.61	8.46	12.56	12.33	5.82	8.20	11.67	12.88
Bahamas: Bimini	—	21.30	30.12	48.02	20.15	8.50	14.76	17.73	4.52	30.89	—	—
Hawaii: Mauna Loa	—	—	16.14	31.51	24.36	26.40	14.37	12.27	10.17	5.59	3.46	5.47
P.R: San Juan	—	6.64	23.38	31.17	14.66	11.93	13.16	13.88	6.84	[b]6.92	[b]4.21	5.28
Panama: Balboa	—	6.03	11.26	23.31	2.18	.85	5.66	3.26	[b]1.29	.09	[b].90	2.44
Ecuador: Guayaquil	—	[b]1.83	[b]1.60	[b].75	1.72	[b].71	1.26	1.97	(c)	[b].48	2.09	3.71
Peru: Lima	—	3.86	(c)	2.25	1.31	1.60	2.17	4.67	[b]2.80	4.33	5.07	3.81
Bolivia: Chacaltaya	—	[b].62	.86	1.82	1.08	2.32	7.58	10.18	10.45	4.64	3.17	3.19
Chile: Antofagasta	—	[b]6.75	3.42	2.16	1.91	2.40	3.70	4.90	3.96	3.21	3.99	[b]3.05
Isle de Pasqua-Easter Island	3.73	[b]1.16	—	1.77	—	—	—	—	—	—	—	—
Portillo	—	—	—	—	—	—	7.53	16.01	[b]1.63	—	—	—
Santiago	—	5.72	4.47	2.21	4.05	[b]1.50	2.49	5.83	3.93	3.37	8.23	4.67
Puerto Montt	—	2.79	2.51	1.39	.79	1.21	[b].92	2.08	1.57	(c)	1.55	2.29
Punta Arenas	—	2.23	2.49	1.36	.94	[b].60	[b].96	[b].47	.84	[b].66	.56	[b]3.10

[a] Errors are less than 20 percent except:
[b] error between 20–100 percent.
[c] error greater than 100 percent.
—, no data reported.

Table 10. Quality control results on blank samples—1968 (Values in dpm/sample ±1 standard deviation)

Month	Iron-55	Strontium-89	Strontium-90	Zirconium-95	Cesium-137	Cerium-141	Cerium-144	Plutonium-238	Plutonium-239
January	42	7.5	0	2.5	NA	13	1.5	.34	.04
February	24	NA	.5	3.0	NA	NA	2.0	NA	NA
March	62	NA	23.8	0	NA	NA	6.7	.18	.09
April	0	NA	0	1.4	NA	NA	5.4	0	0
May	0	NA	0	0	NA	NA	0	.29	.03
June	96	NA	1.6	3.1	NA	NA	0	.37	0
July	NA	7.1	.5	.9	0.2	NA	2.1	.36	.12
August	NA	0	.5	9.3	.7	NA	2.0	.29	.05
September	NA	0	0	2.8	1.5	NA	1.6	.41	0
October	NA	NA	0	NA	5.2	NA	3.0	.11	0
November	NA	NA	.1	5.7	.9	NA	.9	.06	0
December	NA	NA	.9	13.5	.1	NA	220	.11	0

NA, no analysis.

Table 11. Quality control results on standard samples, 1968 (average values in percent deviation)

Month	Iron-55	Strontium-89	Strontium-90	Zirconium-95	Cesium-137	Cerium-144	Plutonium-238	Plutonium-239
January	12.5	−12.5	−4.0	−13.0	NA	−2.0	−8.5	−3.5
February	18.0	NA	−16.0	−19.5	NA	−1.5	17.0	3.0
March	21.5	NA	−1.0	−21.0	NA	−3.0	15.5	.5
April	5.5	NA	−5.5	−13.5	NA	.5	16.0	−.5
May	−5.0	NA	−22.0	−22.0	NA	2.5	9.5	1.0
June	13.0	NA	−9.0	−16.0	NA	3.5	10.0	1.0
July	NA	NA	1.0	−6.0	11.0	10.0	10.0	1.0
August	NA	66.5	−13.5	−6.0	−5.0	−2.0	29.0	−3.5
September	NA	−11.5	−6.5	−7.0	−8.0	2.0	9.0	.5
October	NA	NA	−3.5	NA	−6.0	1.0	26.5	2.0
November	NA	NA	−1.5	−11.5	NA	8.0	30.0	6.1
December	NA	NA	−5.0	−14.8	1.0	4.5	35.0	3.9

NA, no analysis.

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance, and environmental monitoring around nuclear facilities.

Strontium-90 in Human Bone, April-June 1970[1]

Radiation Office
Environmental Protection Agency

To obtain data on the concentration of strontium-90 in man by age and geographical region, the Public Health Service began collecting human bone specimens in late 1961. Analyses of selected samples of people in older-age groups have shown their bone strontium-90 content to be low and age independent (1). Consequently, the target population includes children and young adults up to 25 years of age.

Although a few samples come from living persons as a result of surgical procedures, the majority are obtained post mortem. In the latter case, the specimens are limited to accident victims or persons who have died of an acute disease process that was not likely to impair bone metabolism. For analytical purposes, a sample of at least 100 grams of wet bone is desired. Generally, this amount is readily available from older children, but it presents some difficulties from the standpoint of infants and children under 5 years of age. Most specimens received to date have been vertebrae and ribs.

Laboratory procedures

The bones are analyzed at the Northeastern Radiological Health Laboratory at Winchester, Mass. Sample collection and preparation are explained elsewhere (*2*). Strontium-90 is measured by tributyl phosphate extraction of its yttrium daughter, which is precipitated as an oxalate. The strontium-90 content is then calculated (*3*) from the yttrium-90 activity. For the purpose of maintaining analytical reproducibility, "blind"

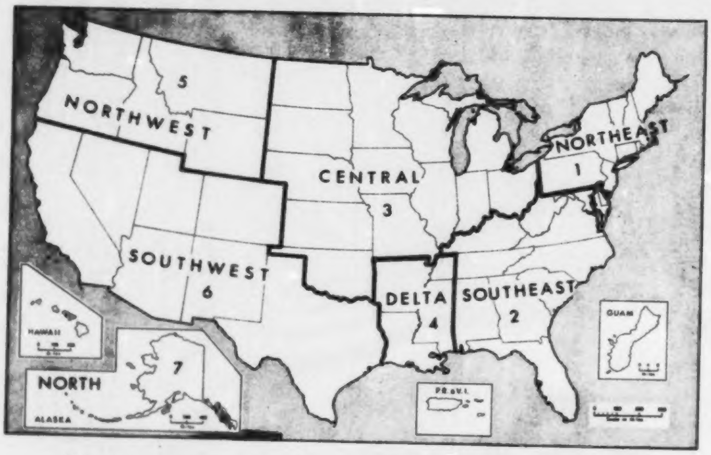

Figure 1. Geographical regions for human bone sampling

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[1] Period during which death or surgical procedure occurred.

Table 1. Strontium-90 in human bone, April–June 1970

Bone region and State	Bone type[a]	Age[b] (years)	Sex	Strontium-90 concentration[c] (pCi/kg bone)	Calcium concentration (g/kg bone)	^{90}Sr/Ca (pCi/g)
Northeast:						
Pennsylvania	V	1	M	86.0± 9.8	32.4	2.65
Massachusetts	V	3	F	57.4± 6.3	26.4	2.18
Maine	V	4	M	95.3± 8.5	25.7	3.71
Massachusetts	V	4	M	71.2± 9.4	26.7	2.67
Rhode Island	V	4	F	63.3± 8.3	29.3	2.16
Massachusetts	V	5	F	85.1±10.7	27.7	3.08
Pennsylvania	V	5	M	80.7± 9.6	33.9	2.38
New York	V	6	M	111.0± 8.6	32.3	3.44
Massachusetts	V	6	M	68.3± 8.3	32.1	2.13
	V	6	M	86.1± 9.9	34.1	2.53
New York	V	7	M	114.1±12.7	48.4	2.36
Massachusetts	V	7	F	76.7± 7.2	28.4	2.70
	V	8	M	67.5± 8.7	27.4	2.46
New York	V	8	M	41.3± 7.7	24.2	1.71
Pennsylvania	V	9	M	53.8± 7.7	39.0	1.38
	V	9	F	82.3±12.1	49.9	1.65
Massachusetts	V	9	M	45.4± 7.1	27.1	1.68
Rhode Island	S	10	M	22.2± 4.0	11.9	1.86
Massachusetts	V	11	F	104.0±11.0	28.3	3.67
Pennsylvania	V	12	M	110.4± 9.9	44.6	2.48
New York	V	12	M	81.5± 7.8	44.6	1.83
Maine	V	13	M	94.0± 9.2	39.4	2.39
Massachusetts	V	13	F	65.3± 6.6	36.6	1.79
New York	V	13	M	86.5± 7.2	41.5	2.09
Massachusetts	V	14	M	129.6±10.9	32.2	4.02
Pennsylvania	V	15	M	60.1± 6.3	41.0	1.47
	V	17	M	130.0± 9.5	53.4	2.44
	V	17	M	121.6±12.5	54.8	2.22
	V	17	M	165.1±16.9	64.9	2.54
Massachusetts	V	17	F	84.8±11.2	48.8	1.74
Pennsylvania	V	17	M	142.5±12.3	49.3	2.89
	V	17	M	107.5± 8.7	50.5	2.13
Massachusetts	V	17	F	98.0±11.6	55.0	1.78
New York	V	17	F	62.0± 7.0	36.9	1.68
Pennsylvania	V	18	M	67.5± 8.9	54.1	1.25
	V	18	M	80.5± 9.8	48.5	1.66
	V	19	F	69.4± 7.8	55.0	1.26
Massachusetts	V	19	F	73.7± 7.4	38.7	1.91
New York	V	20	M	72.9±10.1	58.8	1.24
Pennsylvania	V	20	M	84.3±11.0	45.9	1.84
New Jersey	V	20	M	99.7±11.5	61.1	1.63
Massachusetts	V	21	M	60.5± 9.3	42.7	1.42
Pennsylvania	V	21	M	78.1±12.4	60.1	1.30
	V	22	M	73.2± 7.6	54.6	1.34
Massachusetts	V	23	M	123.6±13.7	54.8	2.26
	V	23	M	96.4± 8.5	50.8	1.90
Pennsylvania	V	25	F	110.2±12.5	56.9	1.94
Massachusetts	V	25	M	49.7± 8.2	46.1	1.08
	V	25	M	73.1± 7.7	40.8	1.79
Southeast:						
South Carolina	V	1	M	64.1±10.3	30.0	2.13
	V	5	F	82.0± 9.7	31.4	2.61
	V	6	M	58.5± 6.9	34.3	1.70
	V	6	M	94.7±12.7	80.5	1.18
	V	8	M	52.4± 6.5	33.6	1.56
	V	10	M	67.8± 8.5	32.9	2.06
Maryland	V	11	M	127.8±14.9	38.1	3.35
North Carolina	V	13	F	49.6± 6.5	25.6	1.94
	V	15	F	118.9± 9.8	36.6	3.25
Maryland	V	17	M	115.1± 9.3	53.0	2.17
South Carolina	V	18	F	40.7± 7.9	30.3	1.34
	V	18	F	99.4± 9.1	62.1	1.60
Maryland	V	20	M	110.9±13.7	52.1	2.13
South Carolina	V	22	M	96.9±11.5	30.3	3.20
	V	23	F	61.3± 8.7	41.6	1.47
Maryland	V	23	M	82.8± 7.5	44.0	1.88
Central:						
Ohio	V	0	M	41.3± 5.9	28.6	1.44
Wisconsin	V	1	M	66.5± 9.3	25.4	2.62
Michigan	V	3	F	50.3± 7.6	25.7	1.96
Wisconsin	V	3	M	31.1± 6.0	30.0	1.04
Michigan	V	3	F	88.7± 9.5	34.7	2.55
	V	3	F	147.4±12.8	31.5	4.68
Ohio	V	3	M	93.0±10.5	29.3	3.17
	V	4	F	57.2± 7.5	32.2	1.77
	V	4	F	44.2± 5.4	27.3	1.62
Michigan	V	5	F	108.4± 9.3	39.1	2.77
Ohio	V	5	F	77.0± 7.0	27.3	2.83
Wisconsin	V	6	F	84.2± 8.3	35.1	2.40
	V	7	F	68.2± 8.9	34.8	1.96
Ohio	V	8	F	62.6± 7.[illegible]	39.9	1.57
Michigan	V	8	F	63.9± 7.8	37.5	1.70
Ohio	V	8	M	61.9± 7.3	28.9	2.14
Michigan	V	9	F	75.3± 8.1	32.0	2.35

Table 1. Strontium-90 in human bone, April–June 1970

Bone region and State	Bone type[a]	Age[b] (years)	Sex	Strontium-90 concentration[c] (pCi/kg bone)	Calcium concentration (g/kg bone)	^{90}Sr/Ca (pCi/g)
Wisconsin	V	10	M	38.0± 6.4	39.1	0.97
Ohio	V	11	M	60.7±11.2	44.1	1.58
Wisconsin	V	11	F	41.9± 5.2	38.9	1.08
Ohio	V	11	F	69.7± 8.6	49.7	1.40
	V	11	M	58.9± 6.8	33.3	1.77
Michigan	V	14	M	57.5± 8.9	36.1	1.59
Ohio	V	14	M	88.2± 9.1	55.2	1.60
	V	14	M	149.4±11.8	59.9	2.49
Michigan	V	14	M	90.8±12.2	56.6	1.60
Ohio	V	14	M	74.7± 8.1	46.2	1.62
	V	15	M	145.6±14.0	57.1	2.55
	V	15	M	121.9±10.5	56.7	2.15
	V	16	M	121.7± 9.4	49.6	2.45
	V	16	F	101.6±12.9	58.0	1.75
	V	16	M	91.5±10.4	52.5	1.74
	V	16	M	85.2± 9.4	32.1	2.65
	V	16	M	81.8±11.[illegible]	43.1	1.90
	V	18	F	68.7± 8.[illegible]	43.1	1.59
Central:						
Michigan	V	18	F	69.2± 8.3	46.6	1.48
Minnesota	V	18	M	141.1± 9.5	49.9	2.83
Michigan	V	18	F	130.6±13.2	55.3	2.36
Ohio	V	19	F	143.8±13.1	71.1	2.02
	V	19	F	164.9±14.7	49.1	3.36
	V	20	M	69.2± 7.2	52.1	1.33
	V	20	M	103.0± 9.0	48.7	2.11
	V	21	M	81.0±12.4	71.7	1.13
	V	21	F	105.4± 9.9	56.4	1.87
	V	22	M	72.2±11.6	55.9	1.29
Michigan	V	23	M	82.4± 7.8	52.1	1.58
Ohio	V	23	F	77.7± 7.3	48.1	1.62
	V	24	M	58.0± 8.3	55.4	1.05
	V	24	M	131.2±12.8	61.0	2.15
Delta:						
Louisiana	V	4	M	98.9±13.7	34.2	2.89
Northwest:						
Oregon	V	3	M	87.4±11.1	66.0	1.32
	V	12	M	68.0± 7.6	37.8	1.80
	V	18	F	70.2± 6.8	23.7	2.96
Washington	V	18	M	80.5± 9.6	47.5	1.69
Oregon	V	20	M	56.7± 6.0	40.6	1.40
Washington	V	20	M	92.0±11.5	57.3	1.61
Oregon	V	23	M	60.8± 9.5	48.0	1.27
	V	24	F	63.3± 9.4	51.4	1.23
Southwest:						
Texas	V	6	M	29.1± 5.2	22.3	1.31
California	S	15	M	18.5± 3.0	14.6	1.26
Texas	V	16	M	141.6±12.5	44.6	3.18
	V	17	F	88.7±12.2	51.8	1.71
California	V	18	M	62.5± 7.7	54.4	1.15
Texas	V	22	F	86.3± 8.9	44.3	1.95
North:						
Alaska	R	16	F	618.5±47.1	132.5	4.67
	R	21	M	255.7±31.7	130.9	1.95

[a] Type of bone: V, vertebrae, S, sternum, R, rib.
[b] Age given as of last birthday prior to death.
[c] Two-sigma counting error.

duplicate analyses are performed on 10 to 20 percent of the samples.

The analytical results for strontium-90 in individual bones from persons dying during the second quarter (April–June) of 1970 are presented in table 1 in order of increasing age within each geographical region. These regions are indicated in figure 1. Reported values are given in picocuries of strontium-90 per kilogram of bone (as a rough indication of dose) and per gram of calcium (for comparison with other data and for purposes of model development). Two-sigma counting errors are reported for the bone concentration.

Following the pattern of earlier reports, subsequent articles will continue to provide interpretation of the data at appropriate stages in the program (*2–6*).

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Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
April–June 1969	May 1970
July–September 1969	June 1970
October–December 1969	September 1970
January–March 1970	January 1971

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1]

Summaries of the environmental radioactivity data follow for the National Reactor Testing Station and the Portsmouth Area Gaseous Diffusion Plant.

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[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. National Reactor Testing Station[2] July–December 1969 and Annual Summary 1969

Health Services Laboratory
U.S. Atomic Energy Commission
Idaho Falls, Idaho

Data from the environmental monitoring network on and around the National Reactor Testing Station (NRTS) in eastern Idaho revealed that NRTS operations during the second half of 1969 did not contribute significantly to environmental radiation or radioactivity concentration levels. These levels remained well below the Atomic Energy Commission (AEC) standards as set forth in AEC Manual Chapter 0524. These standards are based on Federal Radiation Council recommendations. The concentrations of radioactivity reported include contributions from all sources, such as fallout and natural radioactivity. Samples of air, water, and milk are collected routinely at stations shown in figure 1. The results of the analyses performed on the air, water, and milk samples are shown in table 1 for July–December 1969 and table 2 for the year 1969.

Water monitoring

Water containing small quantities of radioactivity is returned to the ground through ponds and wells at the NRTS. The radioactivity in the water is measured before discharge to make sure that standards are not exceeded in the environment. Radioactivity is also monitored in the

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[2] Summarized from "Environmental Monitoring Report No. 25, July–December and Annual Summary 1969, U.S. Atomic Energy Commission, Idaho Operations Office, Health Services Laboratory.

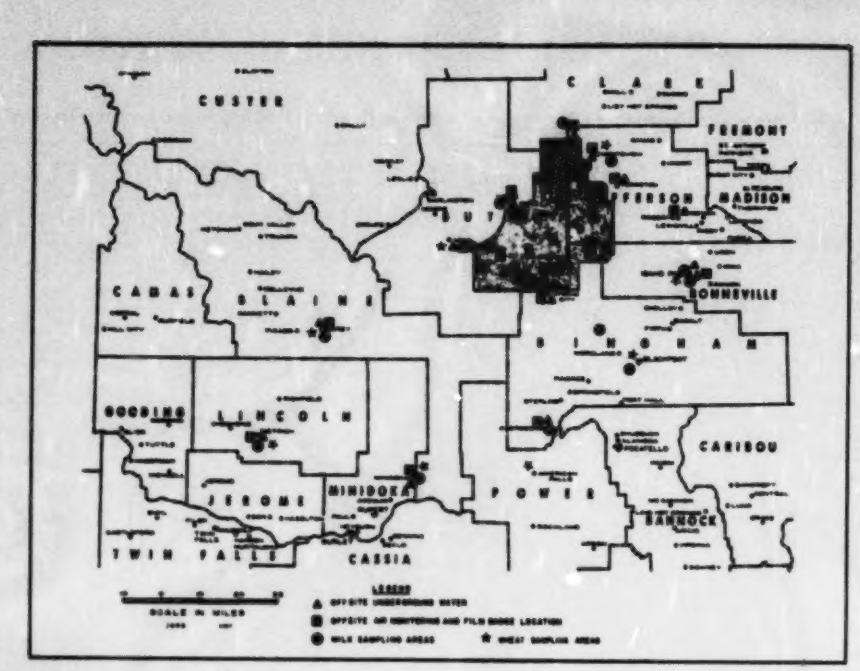
CUSTER
CLARK
FREMONT
FERSON
MADISON
BUT
CAMAS
BLAINE
BONNEVILLE
BINGHAM
GOODING
LINCOLN
CARIBOU
JEROME
MINIDOKA
POWER
BANNOCK
TWIN FALLS
CASSIA
SCALE IN MILES
LEGEND
OFFSITE UNDERGROUND WATER
OFFSITE AIR MONITORING AND FILM BADGE LOCATION
MILK SAMPLING AREAS
WHEAT SAMPLING AREAS

Figure 1. Environmental monitoring stations, National Reactor Testing Stations

ground water from onsite and offsite sampling locations. Samples are analyzed for gross alpha and gross beta radioactivity and tritium. Offsite surface water samples are also collected from the Snake River at Idaho Falls and Bliss, Idaho. Because offsite background concentrations were not detectable, no radioactivity representing background was subtracted from the levels measured onsite. The average concentrations of all types of radioactivity in onsite and offsite water were less than 11 percent of all respective AEC guides. The standard for onsite drinking water was changed in February 1969 from the 40-hour-per-week restricted area standard to the same standards that apply to offsite water. Radioactivity above the detection level was measured in only 4 offsite water samples during 1969.

Air monitoring

Radioactive materials in the atmosphere are collected by drawing air through filters. The samplers operate continuously, and the filters are changed weekly. The filters are analyzed for gross alpha, gross beta, and iodine-131 radioactivity. Samplers are located at eight locations onsite as shown in figure 1. The offsite gross beta and iodine-131 concentrations reported were determined from samples at Idaho Falls, Blackfoot, and Arco. The onsite gross beta and iodine-131 average levels in air were not significantly different from offsite background levels in air during 1969. The gross alpha sampling results from Arco were used as the background to which the onsite alpha air activities were compared. The Arco station was used because it has the lowest concentrations of natural alpha radioactivity. The Idaho Department of Health is conducting investigations with the help of the Health Services Laboratory to determine the cause of the airborne radioactivity concentrations at Blackfoot and Idaho Falls, which are slightly higher than at Arco or the NRTS. There was no significant difference between the NRTS and Arco's gross alpha radioactivity. All air monitoring results are listed in tables 1 and 2.

Table 1. Environmental monitoring data for the National Reactor Testing Station, July–December 1969

Type of sample and units	Number of samples	Type of radioactivity	Minimum level of detection	Maximum radioactivity of single sample	Average radioactivity per sample	AEC standard
Onsite production well water (pCi/liter)	200	Alpha	3	3 6	<3	30
		Beta	5	113	<7	100
		Tritium	[a]2	[a]75	[a]7.7	[a]3,000
Offsite underground water (pCi/liter)	12	Alpha	3	<3	<3	30
		Beta	5	<5	<5	100
		Tritium	[a]2	[a]<2	[a]<2	[a]3,000
Surface water (pCi/liter)	2	Alpha	3	<3	<3	30
		Beta	5	<5	<5	100
		Tritium	[a]2	[a]<2	[a]<2	[a]3,000
Onsite air (pCi/m^3)	208	Alpha	.001	.007	.003	0.6
		Beta	.003	2.95	.53	300
		Iodine-131	.01	.12	<.01	9,000
Offsite air (pCi/m^3)	104	Alpha	.001	.005	.003	0.02
		Beta	.003	1.28	.41	10
		Iodine-131	.01	.065	<.01	100
Offsite milk (pCi/liter)	85	Iodine-131	20	<20	<20	[b]100
		Strontium-90	1	12	<3.9	[b]200
Offsite wheat (pCi/kg)	8	Strontium-90	2	13	<7.5	None
External radiation, thermoluminescent dosimeters: (mrem/6 months less natural background)						
Offsite perimeter locations	35	Gamma	5	15	6	85
On and offsite public highways:						
Highway 20	35	Gamma	5	<5	<5	85
Highway 28	19	Gamma	5	<5	<5	85
Highway 22	8	Gamma	7	<7	<7	85
Highway 28	4	Gamma	7	<7	<7	85

[a] Concentration of tritium in nCi/liter.
[b] The continuous intake guide recommended by the Federal Radiation Council.

Table 2. Environmental monitoring data for the National Reactor Testing Station, January–December 1969

Type of sample and units	Number of samples	Type of radioactivity	Minimum level of detection	Maximum racioactivity of single sample	Average radioactivity per sample	AEC standard
Onsite production well water (pCi/liter)	504	Alpha	3	6	<3	30
		Beta	5	113	<6.6	100
		Tritium	[a]2	[a]85	[a]8.3	[a]3,000
Offsite underground water (pCi/liter)	24	Alpha	3	4	<3	30
		Beta	5	5	<5	100
		Tritium	[a]2	[a]<2	[a]<2	[a]3,000
Surface water (pCi/liter)	4	Alpha	3	<3	<3	30
		Beta	5	<5	<5	100
		Tritium	[a]2	[a]<2	[a]<2	[a]3,000
Onsite air (pCi/m^3)	416	Alpha	.001	.023	.003	.6
		Beta	.003	2.95	.50	300
		Iodine-131	.01	.12	<.014	9,000
Offsite air (pCi/m^3)	208	Alpha	.001	.011	.003	.02
		Beta	.003	1.6	.43	10
		Iodine-131	.01	.14	.016	100
Offsite milk (pCi/liter)	176	Iodine-131	20	<20	20	[b]100
		Strontium-90	1	12	<3.2	[b]200
Offsite wheat (pCi/kg)	8	Strontium-90	2	13	<7.5	None
External radiation, thermoluminescent dosimeters: (mrem/6 months less natural background)						
Offsite perimeter locations	41	Gamma	10	[c]15	<11	170
On and offsite public highways:						
Highway 20	73	Gamma	10	[c]18	<10	170
Highway 28	38	Gamma	10	[c]7	<10	170
Highway 22	16	Gamma	12	[c]<7	<12	170
Highway 28	8	Gamma	12	[c]<7	<12	170

[a] Concentration of tritium in nCi/liter.
[b] The continuous intake guide recommended by the Federal Radiation Council.
[c] mrem/6 months.

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Offsite milk monitoring

Offsite milk samples are collected from 12 locations routinely and analyzed for strontium-90 and iodine-131. A composite grade A sample is collected weekly from an Idaho Falls dairy. This composite sample contains milk from areas north, south, and east of NRTS. Milk samples are collected monthly from all sampling locations. The sampling locations are shown in figure 1, and the results are given in tables 1 and 2. No iodine-131 was detected at any time during the year. The strontium-90 concentrations in milk, including background, were less than 4 percent of the standard during 1969 and are attributed to worldwide fallout.

Wheat monitoring

Wheat samples (grain only) were collected during harvest from eight different locations. The wheat hull contains about 90 percent of the strontium-90 radioactivity. This means that only 10 percent of the radioactivity will remain after processing the wheat for use in food products. No guide has been established for the radioactivity content of field samples of wheat. The concentration of strontium-90 in wheat is attributed to worldwide fallout. The sampling locations are shown in figure 1 and the analysis results in tables 1 and 2.

Gamma radiation levels

The external gamma radiation is measured with thermoluminescent dosimeters (TLD). The exposure results reported in tables 1 and 2 represent net values after subtracting natural background exposures. An average background was determined from dosimeters placed at the offsite locations of Aberdeen, Carey, Deitrich, Idaho Falls, and Minidoka. The offsite perimeter locations are Arco, Atomic City, Butte City, Howe, Monteview, Mud Lake, and Roberts. No significant radiation exposures were observed during 1959. The maximum exposure was less than 8 percent of the AEC radiation protection standards.

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
July–December 1968	June 1970
January–June 1969	January 1971

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2. Portsmouth Area Gaseous Diffusion Plant[3] January–June 1970

Goodyear Atomic Corporation
Piketon, Ohio

The separation of uranium isotopes by the gaseous diffusion process presents control problems similar to any chemical process using toxic solvents and extraction solutions. Natural uranium and thorium-234 are the most likely radionuclides to be released to the environment by the Portsmouth Area Gaseous Diffusion Plant. To verify the effectiveness of plant controls, environmental monitoring is conducted for evidence of alpha-particle, beta-particle, and gamma-ray emitters.

Previously, environmental radiation reports have reflected air sample results for both alpha and beta-gamma radioactivity taken at 21 offsite locations. These samples were taken once per month at each location. In April 1970, the Atomic Energy Commission requested that Goodyear Atomic Corporation report only the results of air samples taken from a minimum of four offsite sampling locations. Sampling at these locations should be at a frequency of at least three, 1,000 cubic foot samples per week. In selecting sample locations, the prevailing wind direction and the locations with the highest concentrations should be considered as indicated in previous reports. The air sample results in this report reflect this request.

Water samples are collected monthly at each location. The one-half gallon sample is analyzed for gross alpha and gross beta-gamma radioactivity. Moderate volumes of low-level water wastes are discharged to the Scioto River System by way of Little Beaver Creek, Big Beaver Creek and Salt Creek. Sampling point distribution is as follows: one on each of the three plant drainage ditches; one on Salt Creek; three each on the Little Beaver Creek, the Big Beaver Creek, and the Scioto River. The frequency of composite sampling of water is determined by the flow at each of the three plant drainage ditches. The composite sample is collected in a 55-gallon drum. After thoroughly mixing the water in the drum, a one-half gallon sample is drawn off each month and the drum drained. The average concentrations in the Scioto River have been substantially below the AEC Radiation Protection Standards for population groups in uncontrolled areas without need for control of releases.

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[3] Data summarized from B. Kalman and S. H. Hulett, "Environmental Radiation Levels and Concentrations, First Half 1970." (September 14, 1970)

For January–June 1970, the alpha and beta-gamma radioactivity in water, and the alpha radioactivity in air decreased when compared with the 1969 calendar year values.

Penetrating background dose rates for the first half of 1970 remained essentially the same when compared with the calendar year 1969 values. External gamma radiation levels are taken at each location once per month. Measurements are taken with a calibrated Geiger-Mueller tube at a distance of 1 foot above ground level. These measurements are extrapolated to a distance of 3 feet. The 3-foot value has been experimentally determined as being approximately two-thirds that at the 1-foot level. These results are tabulated in µrem/h.

Average alpha and beta-gamma radioactivity concentrations in air are summarized in table 3. Table 4 contains the average alpha and beta-gamma radioactivity concentrations in water. The external gamma-ray levels, measured at the sampling locations shown in figure 2, are summarized in table 5. The overall average concentrations and background exposure rates for January–June and July–December 1969 and January–June 1970 are presented in table 6.

Table 3. Radioactivity in air, Portsmouth Plant, January–June 1970

Location	Number of samples	Alpha radioactivity concentration (fCi/m³)			Average as a percent of AEC standards[a]	Beta-gamma radioactivity concentration (pCi/m³)			Average as a percent of AEC standards[a]
		High	Low	Average		High	Low	Average	
3	38	145	<16	32	0.81	2.7	<0.016	.85	0.09
12	36	692	<16	48	1.21	2.1	< .016	.71	.07
24	37	209	<16	32	.81	1.6	< .016	.61	.06
29	35	145	<16	32	.81	1.7	< .016	.63	.06
Average	146	692	<16	36	.91	2.7	< .016	.70	.07

[a] The AEC radiation protection standard for alpha radioactivity in air–4 pCi/m³ (insoluble uranium-235), beta-gamma radioactivity–1 nCi/m³ (insoluble thorium-234); sensitivity of analysis for both alpha and beta radioactivity is 16.1 fCi/m³.

Table 4. Radioactivity in water, Portsmouth Plant, January–June 1970

Location	Number of samples	Alpha radioactivity concentration (pCi/liter)			Average as a percent of AEC standards[a]	Beta-gamma radioactivity concentration (pCi/liter)			Average as a percent of AEC standards[a]
		High	Low	Average		High	Low	Average	
1	6	4.5	<0.5	1.8	<0.01	72.0	<14.0	<14.0	<0.07
2	6	9.0	.9	3.3	.01	<14.0	<14.0	<14.0	< .07
3[b]	6	22	< .5	6.8	.02	18.0	<14.0	<14.0	< .07
4	6	2.7	< .5	.9	< .01	22.5	<14.0	<14.0	< .07
5	6	2.7	< .5	.9	< .01	<14.0	<14.0	<14.0	< .07
6	6	3.2	< .5	.9	< .01	22.5	<14.0	<14.0	< .07
7	6	110	18	46	.16	441	<14.0	125	.63
8	6	90	32	59	.20	112	<14.0	59.9	.30
10[b]	6	9.0	< .5	5.4	.02	58	<14.0	20.3	.10
11[b]	6	290	110	180	.60	554	<14.0	332	1.7
12	6	18	< .5	3.8	.01	31.5	<14.0	<14.0	< .07
13	6	58	< .5	12	.04	117	<14.0	30.6	.15
14	6	14	< .5	6.8	.02	22.5	<14.0	<14.0	< .07
Average	78	290	< .5	25	.08	554	<14.0	43.7	.22

[a] The AEC radiation protection standard for alpha radioactivity in water–30 nCi/liter (uranium-235), beta-gamma radioactivity–20 nCi/liter (thorium-234); sensitivity of analysis, alpha radioactivity–0.5 pCi/liter; beta radioactivity–14.0 pCi/liter.

[b] Composite sample.

Table 5. Background exposure rates, Portsmouth Plant January–June 1970

Location	Number of samples	Background rate[a] (μrem/h)			Background average rate extrapolated to 3-foot level (μrem/h)
		High	Low	Average	
2	5	13.1	10.0	11.7	7.8
3	37	27.6	9.0	12.9	8.0
4	5	12.9	10.7	11.9	7.9
6	5	12.4	10.9	11.7	7.8
9	5	12.9	9.3	11.7	7.8
12	35	13.8	9.8	12.1	8.1
13	5	12.9	10.9	11.9	7.9
15	5	12.9	10.0	11.7	7.8
16	5	12.6	10.0	11.9	7.9
17	5	13.8	10.7	12.1	8.1
18	5	12.6	9.5	11.9	7.9
19	5	12.3	10.2	12.4	8.3
20	5	14.3	10.2	12.4	8.3
21	5	12.4	10.5	11.7	7.8
22	5	11.7	10.5	10.9	7.3
23	4	13.8	10.5	11.9	7.9
24	30	16.4	10.7	13.8	9.2
25	5	13.3	10.2	11.4	7.6
26	5	13.3	9.5	11.9	7.9
27	4	14.0	11.4	12.4	8.3
28	5	13.8	10.9	12.9	8.6
29	34	16.7	12.1	14.0	9.3
Average	230	27.6	9.0	12.1	8.1

[a] Open-shield Geiger tube 1 foot above ground; limit of sensitivity—0.1 μrem/h.

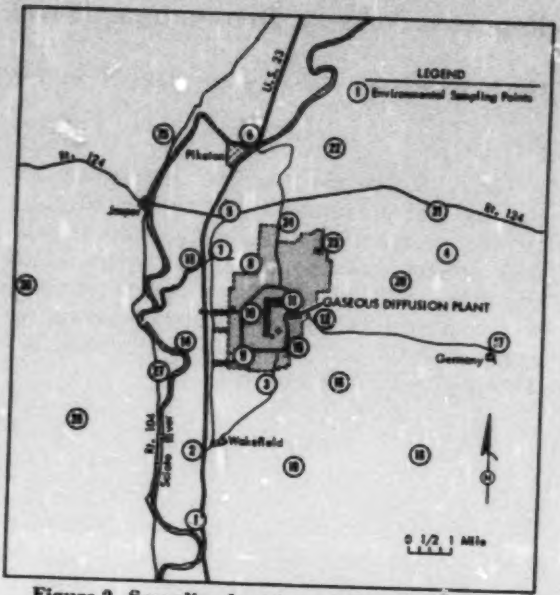

Figure 2. Sampling locations, Portsmouth Area Gaseous Diffusion Plant

Table 6. Comparison of average concentrations, Portsmouth January 1969–June 1970

Type of monitoring	Percent of AEC standard[a]			
	January–June 1969	July–December 1969	Calendar year 1969	January–June 1970
Air:				
Alpha radioactivity	<5.0	[b]10.1	5.7	0.91
Beta-gamma radioactivity	.2	.05	.03	.07
Water:				
Alpha radioactivity	.20	.22	.20	.08
Beta-gamma radioactivity	.38	.29	.32	.22
Background exposure extrapolated to 3 feet above ground level: (μrem/h)	7.9	8.5	8.2	8.1

[a] See footnote (a) of tables 2 and 3. Note units for background exposure.
[b] This value was influenced by three high values in August, however, all values were considerably below the AEC standards. There is no explanation for the high result.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–June 1969	April 1970
July–December 1969	October 1970

Reported Nuclear Detonations, March 1971

(Includes seismic signals presumably from foreign nuclear detonations)

The U.S. Atomic Energy Commission announced that on March 22, 1971, the United States recorded seismic signals, presumably from a Soviet underground nuclear explosion. The signals, which originated in the Semipalatinsk nuclear test area, were equivalent to those of an underground nuclear explosion in the low-intermediate yield range (20–200 kilotons TNT equivalent).

On March 23, 1971, the United States recorded seismic signals, presumably from a Soviet underground nuclear explosion. The signals originated from the southern Ural area and were equivalent to those of an underground nuclear explosion in the low-intermediate yield range (20–200 kilotons TNT equivalent).

There were no announced nuclear tests for the United States for March 1971.

Not all of the nuclear detonations in the United States are announced immediately, therefore, the information in this section may not be complete. A complete list of announced U. S. nuclear detonations may be obtained upon request from the Division of Public Information, U. S. Atomic Energy Commission, Washington, D. C. 20545.

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SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

DOSE ASSESSMENT OF IONIZING RADIATION EXPOSURE TO THE POPULATION. *Michael S. Terpilak*, *Charles L. Weaver*, and *Samuel Wieder*. *Radiological Health Data and Reports*, *Vol. 12*, April 1971, pp. 171–188.

The population dose from natural background, residual weapons test fallout, nuclear power operations, and medical and dental uses of ionizing radiation has been reviewed. Reported and projected population exposures from these sources indicate that, for the near future, the predominant exposure to the public will be attributable to natural background and to medical x rays. A continual evaluation to assess priorities, based on magnitude and type of exposure, and investigations into the biological effects of radiation constitute important features of public health responsibility.

A declining trend is in prospect for exposure to weapons test fallout, in the absence of major atmospheric nuclear explosions. Exposure resulting from all procedures related to nuclear power operations and from diagnostic medical radiation (x rays and internally administered radionuclides) is projected to become of increasing consequence. These warrant increased attention in planning for surveillance. Surveillance associated with peaceful uses of nuclear explosions (Plowshare Program), and with tests of nuclear engines for propulsion, requires individual programming.

KEYWORDS: Dose, genetic, organ, tissue, whole body, ionizing radiation, environment, population, nuclear reactors, radionuclides, assessment, projection.

PUBLIC HEALTH ASPECTS OF IODINE-129 FROM THE NUCLEAR POWER INDUSTRY. *John L. Russell* and *Paul B. Hahn*. *Radiological Health Data and Reports*, *Vol. 12*, April 1971, pp. 189–194.

The production of iodine-129 in nuclear power reactors and its subsequent environmental releases during fuel reprocessing represents a potential long-term public health problem. Because of its extremely long half-life, any discharged iodine-129 is essentially a permanent contaminant in the biosphere, where it will eventually be found as a fraction of total iodine within a locality and possibly worldwide. This potential problem, its possible geographical scope, and the projected impact on population exposure are discussed along with data from measurements at nuclear power reactors and a fuel reprocessing plant.

A concentration of 0.86 percent iodine-129 in total iodine produces the dose limit recommended by the Federal Radiation Council (FRC) for a suitable sample of an exposed population. The quantity of iodine-129 discharged from operating power reactors was estimated from measurements of iodine-131 discharges by calculating an iodine-129 to iodine-131 buildup ratio. This analysis showed that the iodine-129 discharge from operating power reactors was negligible. Measurements at a fuel reprocessing plant indicated that approximately 10 percent of the total iodine-129 inventory in spent fuel was discharged from the stack during the batch dissolution process. The liquid discharge concentrations were about 2 percent of the total iodine-129 inventory. Iodine-129 levels in deer thyroids taken in the reprocessing plant locality were about 40 percent of levels of FRC guidance for human thyroids.

KEYWORDS: Iodine-129, fuel reprocessing plant, power reactor, environmental monitoring, dose, thyroid.

STATISTICAL LIMITS OF ACCURACY AND PRECISION OF GROSS ALPHA AND BETA RADIOACTIVITY MEASUREMENTS IN WATER.

Edmond J. Baratta and *Forrest E. Knowles, Jr. Radiological Health Data and Reports, Vol. 12*, April 1971, pp. 195–198.

This paper presents the results of a technical experiment designed to determine the effectiveness of measurements for gross alpha and beta radioactivity in water. Since this analysis is normally used as a "screening" technique, it is essential that the limits of precision and accuracy of the method be known. Gross measurements are still being used in preoperational reactor surveys as an indication of the "background" levels and to monitor radioactivity when the reactor becomes operational. In addition, the Public Health Service standard for drinking water has, in lieu of a determination of radium-226 and strontium-90, limits for gross alpha and beta radioactivity, respectively.

The precision and accuracy of a standard method for analysis of gross alpha and beta radioactivity in water were determined through the cooperation of private and government laboratories. It was found that gross alpha radioactivity could be determined with an overall precision of 12 percent, while the gross beta radioactivity could be determined with a precision of 7 percent. The accuracy of the gross alpha activity measurements was within 10 percent, and for the gross beta activity measurements, 1 percent.

KEYWORDS: Accuracy, detection limits, gross alpha radioactivity, gross beta radioactivity, precision, water..

☆ U.S. GOVERNMENT PRINTING OFFICE: 1971—[illegible]

RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 12, Number 5, May 1971

Radiological Health Data and Reports, a monthly publication of the Environmental Protection Agency, presents data and reports provided by Federal, State, and foreign governmental agencies and other cooperating organizations. Pertinent original data and interpretive manuscripts are invited from investigators.

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels. This responsibility was delegated to the Bureau of Radiological Health, Public Health Service. Pursuant to the Reorganization Plan No. 3 of 1970, effective December 2, 1970, this responsibility was transferred to the Radiation Office of the Environmental Protection Agency which was established by this reorganization.

The Federal agencies listed below appoint their representatives to a Board of Editorial Advisors. Members of the Board advise on general publications policy; secure appropriate data and manuscripts from their agencies; and review those contents which relate to the special functions of their agencies.

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ENVIRONMENTAL PROTECTION AGENCY
William D. Ruckelshaus, Administrator

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Environmental Monitoring and Disposal of Radioactive Wastes from U.S. Naval Nuclear-Powered Ships and Their Support Facilities, 1970

M.E. Miles, J. J. Mangeno, and *R. D. Burke*[1]

This report summarizes data on disposal of radioactive wastes from U.S. Naval nuclear-powered ships and their support facilities and summarizes results of environmental monitoring performed to confirm adequacy of waste disposal limits and procedures. The total radioactivity discharged into all ports and harbors was 0.024 curies in 1970, less than one hundredth the total annual discharges of the early 1960's. Results of environmental surveys of harbor water and bottom sediment for gross radioactivity and for cobalt-60 show that (1) no increase in radioactivity above normal background levels has been detected in harbor water, (2) discharges of liquid wastes from U.S. Naval nuclear-powered ships have not caused a measurable increase in the general background radioactivity of the environment, and (3) low-level cobalt-60 radioactivity is detectable in localized areas of harbor bottom sediment around a few piers at operating bases and shipyards where maintenance and overhaul of Naval nuclear-powered ships have been conducted over a period of several years; these levels have decreased in recent years.

This report confirms that procedures used by the Navy to control discharges of radioactivity from U.S. Naval nuclear-powered ships and their support facilities have been effective in protecting the health and safety of the general public.

The radioactivity in wastes discussed in this report originates in the pressurized water reactors of U.S. Naval nuclear-powered ships. As of the end of 1970, there were 92 nuclear-powered submarines and four nuclear-powered surface ships in operation. Construction, maintenance, overhaul, and refueling of these nuclear propulsion plants involve nine shipyards, eleven tenders, and two submarine bases. This report first describes disposal of radioactive liquid wastes, then solid wastes. The final section discusses monitoring of the environment to determine the effects of radioactive discharges. This report brings the information in the Navy's 1959 report up to date (*1*).

Radioactive liquid waste disposal

In the shipboard reactors, pressurized water circulating through the reactor core picks up the heat of nuclear reaction. Reactor cooling water circulates through a closed piping system to heat exchangers which transfer the heat to water in a secondary steam system isolated from the primary cooling water. The steam is then used as the source of power for the propulsion plant as well as for auxiliary machinery. Discharges of radioactivity from ships occur primarily when reactor coolant water expands as a result of being heated to operating temperature; this coolant passes through a purification system ion-exchange resin bed prior to discharge.

Liquid wastes discharged by support facilities result from operations such as draining shipboard reactor systems, decontaminating piping systems contaminated with radioactivity, and laundering anticontamination clothing worn by personnel. These facilities are equipped with processing systems to remove most of the radioactivity from liquid wastes prior to discharge into harbors.

The principal source of radioactivity in liquid wastes is from trace amounts of corrosion and wear products from reactor plant metal surfaces. Radionuclides with half-lives greater than one day in these corrosion and wear products include tungsten-187, chromium-51, hafnium-181, iron-59, iron-55, zirconium-95, tantalum-182, manganese-54, cobalt-58, and cobalt-60. The predominant and also longest lived of these is cobalt-60, which has a 5.3 year half-life; cobalt-60 also has the lowest concentration value for water listed by organizations which set radiological standards (*2–4*) for these corrosion and wear radionuclides. Conservatively, therefore, radioactive waste disposal is controlled by assuming that all the long-lived radioactivity is cobalt-60.

---

[1] Nuclear Power Directorate, Naval Ship Systems Command, Department of the Navy.

The total amounts of long-lived radioactivity discharged into harbors and seas within 12 miles from shore during the past 5 years are listed in table 1, which updates information in references 5 through 9. Included are data from U.S. Naval nuclear-powered ships and from supporting shipyards, tenders, and submarine bases. Locations listed in table 1 include operating bases and home ports in the United States and overseas which have been visited by Naval nuclear-powered ships. The quantities of radioactivity listed in this table are reported as if the entire radioactivity consisted of cobalt-60, the predominant long-lived radionuclide.

Although this table shows both gallons and curies discharged, the curie data are the more important. In 1970, the gallons shown in table 1 for most of these organizations are no more than many single U.S. homes discharge to their sewage systems each year.

The table shows that nearly all the radioactive discharges occur where shipyards are overhauling nuclear-powered ships. In 1970, for example, a total of 0.024 curie was discharged into all harbors, including those outside the United States. Essentially all of this came from shipyards overhauling nuclear-powered ships. Less than one percent of the total was discharged into all other harbors entered by U.S. Naval nuclear-powered ships in 1970.

This total radioactivity discharged into harbors is less than the U.S. Public Health Service (PHS) (*10*) reports most individual electrical power-generating nuclear reactors discharge each year. Evaluation by PHS (applicable divisions of which were incorporated into the Environmental Protection Agency (EPA) late in 1970) of the small radioactive discharges from electrical power-generating reactors shows that these discharges caused little or no increase in environmental radioactivity.

The 0.024 curie total from the Navy nuclear propulsion program is less than the 1 curie per year the U.S. Atomic Energy Commission (AEC) regulations (*2*) permit a licensee to discharge into a single sanitary sewage system.

Procedures for liquid wastes in harbor

Discharge limits for radioactive liquid wastes from U.S. Naval nuclear-powered ships and their support facilities are consistent with applicable recommendations issued by the Federal Radiation Council (incorporated into the Environmental Protection Agency late in 1970) AEC, National Council on Radiation Protection and Measurements (NCRP), International Commission on Radiological Protection (ICRP), International Atomic Energy Agency (IAEA), and National Academy of Sciences-National Research Council (NAS-NRC) (*2–4, 11–14*). In consonance with these recommendations, the policy of the U.S. Navy is to minimize the amounts of radioactivity discharged within 12 miles from shore including into harbors. Keeping discharges small minimizes the radioactivity available to build up in the environment or to concentrate in marine life. To implement this policy of minimizing discharges, the Navy has issued standard instructions defining the radioactive waste disposal limits and procedures to be used by U.S. Naval nuclear-powered ships and their support facilities. These instructions were reviewed and concurred with by the U.S. Public Health Service and the U.S. Atomic Energy Commission.

To achieve low discharges, the waste disposal procedures and limits used in the Navy nuclear propulsion program are more stringent than in the preceding references. The following are some of the procedures required by the Navy in shipyards:

a. Shipyard management at all levels is required to be involved in control of radioactive liquid waste.

b. Liquids are segregated to minimize volumes required to be processed as radioactive. Liquids with different chemical contents are collected

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Table 1. Radioactive liquid waste discharged to harbors from U.S. Naval nuclear-powered ships and their support facilities for 1966 through 1970[a, b, c]

Facility	1966		1967		1968		1969		1970	
	Thousand gallons	Curies	Thousand gallons	Curies	Thousand gallons	Curies	Thousand gallons	Curies	Thousand gallons	Curies
Portsmouth, N.H; Naval Shipyard	155	0.011	265	0.012	171	0.006	87	0.002	68	0.002
Groton-New London, Conn; Electric Boat Division, tender at State Pier, and submarine base	1,274	.025	606	.011	400	.006	615	.008	359	.004
Newport News, Va; Newport News Shipbuilding	1,581	.055	1,532	.034	1,146	.025	870	.022	1,466	.013
Norfolk, Va; Naval Shipyard and tender	1,051	.023	1,784	.034	184	.004	102	.005	98	.001
Charleston, S.C; Naval Shipyard and tenders	360	.034	320	.011	227	.004	131	.001	58	<.001
Pascagoula, Miss; Ingalls Nuclear Division	<1	<.001	6	<.001	9	<.001	5	<.001	7	<.001
San Diego, Calif; tenders at Ballast Point	18	.001	28	.001	<1	<.001	<1	<.001	<1	<.001
Long Beach, Calif; Naval Shipyard and Base	8	<.001	<1	<.001	<1	<.001	2	<.001	<1	<.001
Vallejo, Calif; Mare Island Naval Shipyard	270	.187	140	.001	391	.027	80	.001	121	.002
Bremerton, Wash; Puget Sound Naval Shipyard	54	<.001	246	.002	182	.001	152	.001	136	<.001
Pearl Harbor, Hawaii; Naval Shipyard and submarine base	654	.031	683	.008	886	.008	1,279	.008	258	.002
Apra Harbor, Guam	30	<.001	42	.002	26	.001	<1	<.001	<1	<.001
All other harbors, United States and foreign	178	.013	<1	<.001	<1	<.001	<1	<.001	<1	<.001
Totals	5,651	0.381	5,653	0.116	3,601	0.081	3,326	0.048	2,571	0.024

[a] Radioactivity data have been standardized to cobalt-60 (are reported as if the entire radioactivity consisted of cobalt-60) and excludes tritium. Volumes are prior to dilution.

[b] A total of 0.02 curies was discharged into the river at Quincy, Mass., from 1961 through March 1969 when all work on U.S. Naval nuclear-powered ships was discontinued at General Dynamics, Quincy Division. A total of 0.01 curies was discharged into the river near Camden, N.J., from 1960 through June 1967 when all work on U.S. Naval nuclear-powered ships was discontinued at New York Shipbuilding Corporation.

[c] Slight differences in volumes and radioactivity data from past reports result from using more significant figures in this table. Volumes less than 500 gallons are shown as <1 thousand. Curies less than 0.0005 are shown as <0.001

separately to ensure that the most effective waste treatment is used. Dilution is not permitted as a means of processing wastes.

c. Several stages of filtration using various pore-size filters are used to remove small-size radioactive particles in liquid waste. Ion exchange resin and activated carbon are normally used to remove radioactivity from liquid wastes.

d. Each shipyard has a limit specified for the total amount of radioactivity to be discharged during the year.

e. Samples are collected during processing to ensure that liquid wastes are far below the permissible water discharge limits in reference 2. Limits used by shipyards are lower than in reference 2.

f. To ensure against operational error, liquid wastes which have been completely processed are transferred to a final clean tank and again sampled prior to discharge. Discharge from this tank is through a final filter.

g. Each discharge requires formal approval of a discharge permit signed by a designated senior radiological control person.

h. An independent organization within the shipyard audits all aspects of radioactive waste processing. This audit group is separate from the radiological control organization which monitors the actual waste processing work.

i. Audits are also performed by representatives from Naval Reactors headquarters who are assigned full time at each shipyard.

j. To ensure absolute compliance with even the smallest detail of operating procedures, each discrepancy found is brought to management attention for action. Aggressive action on such minor items prevents incidents from occurring.

Other radionuclides

Reactor coolant also contains short-lived radionuclides with half-lives of seconds to hours. The highest concentrations in reactor coolant are from nitrogen-16 (7 second half-life), nitrogen-13 (10 minute half-life), fluorine-18 (1.8 hour half-life), argon-41 (1.8 hour half-life), and manganese-56 (2.6 hour half-life). For the longest-lived of these, about 1 day after discharge from an operating reactor, the concentration is reduced to one thousandth of the initial concentration, and in about 2 days, the concentration is reduced to one millionth. Most discharges from ships occur during heating up prior to power operation of the reactor, when short-lived radionuclides are at low concentrations in coolant. Total short-lived radioactivity in such a discharge is less than 0.001 curie. Because of their small amounts and rapid decay, short-lived radionuclides are less important than long-lived radionuclides for waste disposal considerations.

Fission products produced in the reactor are retained (metallurgically bound) within the fuel alloy. The fission gases, krypton and xenon, are also retained within the fuel elements. However, trace quantities of naturally occurring uranium impurities in reactor structural materials release small amounts of fission products to reactor coolant. The concentrations of fission products and the volumes of reactor coolant discharged are so low, however, that the total radioactivity attributed to the long-lived fission product radionuclides, strontium-90 and cesium-137, in discharges from U.S. Naval nuclear-powered ships and their support facilities has been less than 0.001 curie per year for all harbors combined. Fallout of these same fission products has often been more than this in one rainfall in a single harbor.

Small amounts of tritium are formed in reactor coolant systems as a result of neutron interaction with the approximately 0.015 percent of naturally occurring deuterium present in water and other nuclear reactions. Although tritium has a 12 year half-life, the radiation produced is of such low energy that the radioactivity concentration guide issued by the ICRP and AEC and by other standard-setting organizations is 100 times higher for tritium than for cobalt-60. This tritium is in the oxide form; it does not concentrate significantly in marine life or collect on sediment since it is chemically indistinguishable from water.

Tritium is naturally present in the environment because it is generated by cosmic radiation in the upper atmosphere. Reference 15 reports that the production rate from this source is about 6 million curies per year, which through rainfall causes a tritium inventory in the oceans of about 100 million curies. Because of this naturally occurring tritium, large discharges of tritium would be required to make a measurable change in the background tritium concentration.

The total amount of tritium discharged during each of the last 5 years from all U.S. Naval nuclear-powered ships and their supporting tenders, bases, and shipyards has been less than 200 curies. Most of these discharges have been in the ocean more than 12 miles from shore. This total tritium discharged from the entire nuclear Navy is less than a single, typical, electrical generating, pressurized water reactor-type, nuclear power station discharges each year (*10*). As described above, such discharges are too small to increase measurably the tritium concentration in the environment. Therefore, tritium has been excluded from the data in other sections of this report.

Liquid waste at sea

Radioactive liquid wastes are also discharged at sea under strict controls. These ocean discharges are consistent with recommendations that the Council on Environmental Quality made in 1970 to the President (*16*). Procedures and limits for ocean discharges have been consistent with recommendations made by the NAS-NRC (*12*) and by the IAEA (*13*). Ship discharges have contained much less radioactivity than these reports indicated would be acceptable. Total long-lived radioactivity, excluding tritium, discharged farther than 12 miles from shore by all U.S. Naval nuclear-powered ships and their supporting tenders is shown in table 2 for recent years.

Table 2. Radioactive liquid waste discharged at sea by U.S. Naval nuclear-powered ships and supporting tenders

Year	Quantity (thousand gallons)	Radioactivity (Ci)
1966	1,400	1.2
1967	1,520	1.3
1968	1,630	1.1
1969	1,570	1.7
1970	1,220	.8

Reactor coolant is purified through an ion-exchange resin bed. This resin becomes expended and periodically requires replacement. Expended resin has been discharged at sea, but this practice was discontinued during 1970. When discharged at sea, resin sinks and as it sinks, the radioactive ions in the resin are rapidly replaced by ions of the sea water. Some of the small radioactive particles in the resin bed are dispersed in sea water and the rest sink with the resin beads. The radioactivity is rapidly dispersed in the ocean due to motion of the ship during discharge and subsequent action of wind, waves, and ocean currents.

Resin discharge at sea was performed in accordance with procedures recommended in the NAS-NRC Publication 658, "Radioactive Waste Disposal from Nuclear-Powered Ships" (*12*). Consistent with these recommendations, Navy procedures for resin discharge at sea required that:

1. The ship be more than 12 miles from any land,
2. The water depth be greater than 1,200 feet,
3. The ship not be in known fishing areas, and
4. Other ships not be nearby and not be in the wake.

Publication 658 developed these procedures to assure no adverse impact on the environment if up to 300 nuclear-powered ships each discharge 400 curies of radioactivity every 2 months off the shores of the United States.

Table 3 summarizes resin discharges at sea during the last 5 years. These results show that the total radioactivity discharged in resin by the entire Navy each year has been less than envisaged in the NAS report for a single ship. Diluting this total radioactivity discharged in a year in a volume as small as 1 cubic-mile of seawater reduces the concentration of radioactivity to less than that which occurs naturally in the ocean. Continued effort by the Navy resulted in improvements in 1970 which have permitted discontinuing discharge of ion exchange resin at sea. Expended resin is now packaged for land disposal in AEC- or State-licensed burial grounds as solid radioactive waste.

Table 3. Radioactive resin disposal at sea by U.S. Naval nuclear-powered ships

Year	Cubic feet of resin	Radioactivity (Ci)
1966	110	439
1967	252	259
1968	106	126
1969	406	132
1970	150	60

Two U.S. Navy nuclear-powered submarines have been lost at sea in the Atlantic Ocean. The submarine THRESHER sank 10 April 1963, 100 miles from land in water 8,500 feet deep at latitude 41°45′N and longitude 65°00′W. The submarine SCORPION sank between 21 and 27 May 1968, 400 miles southwest of the Azores in more than 10,000 feet of water. The reactors used in all U.S. Naval submarines and surface ships are designed to minimize potential hazards to the environment even under the most severe casualty conditions such as actual sinking of the ship. First, the reactor core is so designed that it is physically impossible for it to explode like a bomb. Second, the reactor fuel elements are made of materials that are extremely corrosion resistant, even in sea water. The reactor core could remain submerged in sea water for decades without release of fission products while the radioactivity decays since the protective cladding on the fuel elements corrodes only a few millionths of an inch per year. Thus in the event of a serious accident where the reactor is completely submerged in sea water, the fuel elements will remain intact for an indefinite period of time and the radioactive material contained in these fuel elements should not be released. The maximum rate of release and dispersal of the radioactivity in the ocean, even if the protective cladding on the fuel were destroyed, would be so low as to be insignificant.

Radioactive material could be released from this type of reactor only, if the fuel elements were actually to melt and in addition, the high-strength, all-welded reactor system boundary were to rupture. The reactor's many protective devices and inherent self-regulating features are designed to prevent any melting of the fuel elements. Flooding of a reactor with sea water furnishes additional cooling for the fuel elements and so provides added protection against the release of radioactive material.

Radiation measurements, water samples, bottom sediment samples, and debris collected from the area where THRESHER sank were analyzed

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for radioactivity by various laboratories with highly sensitive equipment. Similarly, sea water and bottom sediment samples taken near SCORPION's hull were analyzed for radioactivity. None of these samples showed radioactivity above naturally occurring background levels and none showed evidence of radioactivity released from either THRESHER or SCORPION.

Solid radioactive waste disposal

During maintenance and overhaul operations, solid low-level radioactive wastes consisting of contaminated rags, plastic bags, paper, filters, ion exchange resin, and scrap materials are collected by nuclear-powered ships and their support facilities. High-level radioactive wastes are associated with expended reactor fuel, all of which are transferred to the AEC for processing. Solid materials from ships are not dumped at sea. They are packaged in a support facility or transferred to a shipyard for packaging. For ultimate disposal, the packaged solid radioactive wastes are shipped to burial sites licensed by the AEC or a State under agreement with the AEC since shipyards and shore facilities are not permitted to dispose of radioactive solid wastes by burial on their own sites. Table 4 summarizes total radioactivity and volumes of radioactive solid waste disposal for the last 5 years.

Because of efforts to minimize solid waste, total volumes have remained nearly constant in spite of increasing work caused by increasing numbers of ships. The average annual volume for the entire Naval nuclear propulsion program could be contained in a cube measuring 15 yards on a side. The radioactivity does not require excessively long-time care in the licensed burial grounds since the principal radionuclides do not have half-lives longer than 5 years. In 100 years, such radioactivity will have decayed to 1 millionth of the initial radioactivity. In less than 200 years, the total of all radioactivity in table 4 will have decayed to less than the amount of radioactivity in a single luminous watch dial.

Disposal of solid radioactive wastes at sea is prohibited by the U.S. Navy. There have been two special exceptions to this policy. First, on 8 April 1959, the radioactive reactor vessel and the reactor plant components removed from the sodium-cooled nuclear reactor plant in the submarine

Table 4. Radioactive solid waste from U.S. Naval nuclear-powered ships and their support facilities for 1966 through 1970[a,b]

Facility	1966		1967		1968		1969		1970	
	Thousand cubic feet	Curies	Thousand cubic feet	Curies	Thousand cubic feet	Curies	Thousand cubic feet	Curies	Thousand cubic feet	Curies
Portsmouth, N.H; Naval Shipyard	19	10	30	198	31	151	8	3	14	16
Groton, New London, Conn; Electric Boat Division, tender at State Pier and submarine base	15	1,093	5	17	4	21	8	328	12	140
Newport News, Va; Newport News Shipbuilding	7	9	17	702	14	10	17	382	28	312
Norfolk, Va; Naval Shipyard and tender	4	3	11	86	2	11	6	8	9	146
Charleston, S.C; Naval Shipyard and tenders	8	6	15	52	14	110	15	9	8	6
Pascagoula, Miss; Ingalls Nuclear Division	0	0	0	0	0	0	1	<1	0	0
San Diego, Calif; tenders at Ballast Point	1	<1	1	<1	1	8	<1	2	<1	1
Long Beach, Calif; Naval Shipyard and base	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Vallejo, Calif; Mare Island Naval Shipyard	9	367	9	23	8	7	8	5	12	2
Bremerton, Wash; Puget Sound Naval Shipyard	1	1	14	193	14	48	11	42	18	1,327
Pearl Harbor, Hawaii; Naval Shipyard and submarine base	1	<1	1	1	3	6	4	3	5	4
Totals	65	1,489	103	1,272	92	372	78	788	106	1,954

[a] This table includes all radioactive waste from tenders and nuclear-powered ships. This radioactivity is primarily cobalt-60.

[b] Slight differences from past reports result from using different number of significant figures in this table. Volumes less than 500 cubic feet are reported <1 thousand and less than 0.5 curie is reported <1.

SEAWOLF were escorted by the U.S. Coast Guard to a disposal site in the Atlantic Ocean 120 miles off the east coast of the United States and sunk in 9,000 feet of water at latitude 38° 30′N and longitude 72°06′W. The disposal was conducted at a site approved for sea disposal of radioactive waste by AEC. This disposal site was used by other organizations for a number of years for radioactive waste (*16*). The SEAWOLF components containing approximately 33,000 curies of radioactivity were welded into a steel barge and scuttled. The low corrosion of this steel container in sea water and the method of packaging were designed to prevent any release of radioactivity to the surrounding sea. As of 1970, this radioactivity has decayed to less than 5,000 curies, essentially all cobalt-60.

The second exception was required for radioactive solid wastes from Pearl Harbor, since it was not feasible to establish a burial ground in the volcanic rocks of Hawaii. Therefore an ocean disposal area, 55 miles from shore, was selected with the agreement of the AEC, the PHS, and the Hawaii Department of Health. The Navy Hydrographic Office determined that normal ocean currents at this location are away from shore. Low-level radioactive waste packaged primarily in 55-gallon steel drums weighted with concrete were disposed of by Pearl Harbor Naval Shipyard in 15,000 feet of water at this location, as shown in table 5. The radioactivity in this waste was primarily cobalt-60. In June 1968, use of this ocean disposal area was discontinued by the Navy and wastes have since been shipped to an AEC or State licensed land burial ground in the continental United States.

Table 5. Solid radioactive waste disposal in the ocean at latitude 20°54′N, longitude 161°06′W

Year	Number of disposal operations	Volume (ft³)	Radioactivity (Ci)
1963	1	1,647	0.5
1964	1	1,275	.7
1965	1	672	1.4
1966	1	682	.3
1967	2	1,134	1.0
1968	4	1,720	4.5
Total	10	7,130	8.4

Environmental monitoring

Environmental monitoring surveys for radioactivity are periodically performed in harbors where U.S. Naval nuclear-powered ships are built or overhauled and where these ships have home ports or operating bases. These surveys are performed to verify the adequacy of liquid waste disposal procedures and limits. To ensure thoroughness and objectivity these surveys are made as independent as practicable from waste disposal operations. Samples from each harbor monitored are also checked at least annually by an AEC laboratory to ensure that analytical procedures are correct and standardized. These AEC laboratory results have been consistent with shipyard results. As a further independent check of environmental monitoring, the PHS has conducted detailed surveys of selected harbors (*17,18*). The PHS has monitored the harbors at Charleston, S.C; Pearl Harbor, Hawaii; San Diego, Calif; Vallejo, Calif; New London, Conn; Newport News, Va; and Norfolk, Va. Navy monitoring results have been consistent with these PHS surveys.

The Navy monitoring program initally emphasized analyzing water because it is used by boats and swimmers and because fish live in this water. Surveys were conducted in the harbors before any radioactivity was discharged to establish base levels of gross beta radioactivity of harbor water in the vicinity of berths to be used by nuclear-powered ships and locations where support facilities might discharge processed water. Results showed that superimposed on the naturally occurring radioactivity of 0.3 picocuries of potassium-40 per milliliter of harbor water were large variations of other radioactivity from fallout. Rain water before much dilution in harbor water sometimes has measured more than 100 times higher than this. In addition, rates of introduction of naturally radioactive radium, uranium, thorium, and their associated radionuclides varied. However, in more than 10 years of monitoring sea water for gross beta radioactivity, commencing in 1954 in New London, Conn., and extending to other ports, no increases in water radioactivity were ever discovered which could be attributed to operation of nuclear-powered ships or their support facilities.

Although the general background radioactivity measurements previously used would indicate presence of radioactivity before exceeding

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concentrations permitted *(2)*, more sensitive measurement techniques were adopted in 1965. Currently, five water samples are taken in each harbor once each quarter year in areas where nuclear-powered ships berth and from upstream and downstream locations. These samples are analyzed for gross gamma radioactivity and for cobalt-60 content. Procedures for analysis were selected to detect cobalt-60 if its concentration exceeds 0.1 picocurie per milliliter, which is 300 times lower than the AEC limit *(2)*. No cobalt-60 has been detected in any of the 2,560 water samples from 20 harbors monitored.

Harbor bottom sediment contains many of the remnants of water pollution; the top layer is generally black and has an offensive odor from decomposing organic waste materials. Silt carried by rivers also deposits on harbor bottoms, building up in depth from less than 1 inch per year to more than 3 feet per year. In falling to the bottom, this silt carries radioactivity from the water to the bottom. Therefore, sampling of harbor bottom sediment became part of early Navy environmental monitoring programs to provide advance indication of radioactivity buildup in the harbor.

Initially, dried samples of harbor bottom sediment were measured for gross beta radioactivity. Results varied from 10 picocuries per gram of sediment to 300 picocuries per gram and varied widely from sample to sample and from month to month in a single harbor. However, analysis of these data showed no harbor had increased its general background radioactivity from operations associated with U.S. Naval nuclear-powered ships.

Commencing in 1963 at the Navy's request, the PHS made additional analyses of samples from some harbors to identify radionuclides present in sediment. These analyses showed that cobalt-60 was the predominant radionuclide added to sediment from nuclear reactor operations. Therefore, Navy monitoring procedures were changed to collect from each harbor 20 to 120 sediment samples once each quarter year. Standard 6-inch square samplers modified to collect only the top ½ to 1 inch of sediment are used for all sediment collection. The top layer was selected because it should be more mobile and more accessible to marine life than deeper layers. The samples are analyzed for gross gamma radioactivity and for cobalt-60. Results of the 3,070 sediment samples from harbors in the United States and possessions for 1970 are summarized in table 6. Comparison to previous environmental monitoring data *(5–9)* shows that environmental cobalt-60 levels have been steadily decreasing.

Table 6 shows that some samples taken near liquid waste discharge points show cobalt-60 radioactivity. However, the affected areas are small, and the total cobalt-60 present is small compared to natural radioactivity present in harbors.

The first data column in table 6 includes all

Table 6. Summary of 1970 surveys for cobalt-60 in bottom sediment of U.S. harbors where U.S. Naval nuclear-powered ships have been regularly based, overhauled, or built

Facility	Number of samples with cobalt-60 concentration			Total bottom area with cobalt-60 over 3 pCi/g[c] (km^2)	Estimated total cobalt-60 in top layer of sediment[d] (Ci)
	<3 pCi/g[a]	3-30 pCi/g	>30-300 pCi/g[b]		
Portsmouth, N.H.; Naval Shipyard	176	0	0	0	ND
Groton, New London, Conn.; Electric Boat Division, State Pier, and submarine base	377	86	1	0.1	0.02
Newport News, Va; Newport News Shipbuilding	152	0	0	0	ND
Norfolk, Va; Naval Shipyard and Base	344	0	0	0	ND
Charleston, S.C; Naval Shipyard and Bases	382	0	0	0	ND
Pascagoula, Miss; Ingalls Nuclear Division	212	0	0	0	ND
San Diego, Calif; Navy Pier at Ballast Point	157	0	0	0	ND
Long Beach, Calif; Naval Shipyard and Base	158	0	0	0	ND
Vallejo, Calif; Mare Island Naval Shipyard	444	0	0	0	ND
Bremerton, Wash; Puget Sound Naval Shipyard	141	0	0	0	ND
Pearl Harbor, Hawaii; Naval Shipyard and submarine base	312	0	0	0	ND
Apra Harbor, Guam	128	0	0	0	ND

[a] Minimum detectable radioactivity is approximately 1 pCi/g. Results in units of pCi/cm^3 range from two to four times the value in pCi/g.

[b] No samples from any harbor were greater than 31 pCi/g.

[c] One square kilometer is approximately equal to 0.4 square mile. Areas with cobalt-60 over 3 pCi/g were in immediate vicinity of piers used for berthing nuclear-powered ships.

[d] Where total cobalt-60 in the surface sediment layer is less than 0.01 curies, ND is reported. Samples more than 1-foot-deep from several harbors show that total cobalt-60 present may be two to five times that measured in the surface layer.

samples with less than 3 picocuries of cobalt-60 per gram of sediment. These low levels are difficult to measure because the levels of radioactivity in sediment from other sources are much higher. The value of 30 picocuries per gram was selected for the top of the second range of data since it corresponds to the upper limit for exposure (*2,4*) even if consumed continuously by members of the general public. Although sediment cannot be consumed by humans, it might serve as a food source for marine life. Data on uptake of cobalt-60 from sediment by marine life obtained to date show that in the salt water harbor-bottom environments, no significant buildup of cobalt-60 occurs in marine life. Therefore, the third range of up to 300 picocuries per gram is selected as a range which would not cause members of the general public to receive radiation exposure approaching the values set (*2–4,14*). Concentrations of cobalt-60 up to 300 picocuries per gram are so low that the AEC does not require those who might possess them to be licensed. If concentrations higher than 300 picocuries per gram were to persist over substantial areas of a harbor bottom, further monitoring would be performed to determine if any of this radioactivity were being taken up by marine life for eventual consumption in food. Because of the low concentrations noted in table 6, monitoring of radioactivity in marine life has not been necessary as part of the routine environmental monitoring programs in these harbors.

References 19 and 20 contain evaluations by AEC laboratories of the effects on the environment from the accumulation near points of discharge of radionuclides from several other nuclear reactors. These reports conclude for these other reactors that radioactivity levels much greater than these shown in table 6 have caused no significant exposure to the general public.

An additional part of the environmental analyses has been to compare amounts of radioactivity measured in the environment with amounts discharged. For example, if 0.01 curies were discharged each year for more than 10 years into a single harbor, the maximum total inventory of cobalt-60 in this harbor will be 0.1 curies of cobalt-60, assuming none of this radioactivity is flushed out with river currents, tides, or dredging. If all this radioactivity were spread uniformly over a reasonable area of 1 square kilometer of the harbor bottom, the result would be less than 10 picocuries of cobalt-60 per square centimeter. This cobalt-60 will be distributed deeply through the sediment over the years, resulting in an average concentration less than 1 picocurie of cobalt-60 per gram of sediment. This is less than the amount of cobalt-60 which would be detected by present sensitive environmental monitoring techniques. Results of analyses such as these help confirm the environmental monitoring data of table 6 and confirm that the Navy's waste discharge limits are satisfactory.

In all monitored harbors, shoreline areas uncovered at low tide are surveyed twice per year for radiation levels with sensitive radiation detectors to determine if any radioactivity from bottom sediment washed ashore. All results were the same as background radiation levels in similar areas, 0.010 to 0.040 millirem per hour. Thus, there is no evidence in these ports that radioactivity from sediment is washing ashore.

Film badges are continuously posted at locations outside the boundaries of areas where radioactive work is performed. These films showed that radiation exposure to the general public outside these facilities was not above that received from natural background radiation levels.

Naval nuclear reactors and their support facilities are designed to ensure that there are no detectable discharges of airborne radioactivity to the atmosphere. Filtration equipment is installed in support facilities to ensure removal of airborne radioactivity without release to the atmosphere. Exhaust stacks at support facilities which could have discharged airborne radioactivity have been monitored. There were no discharges of airborne radioactivity to the atmosphere measured above concentrations normally present in the atmosphere.

In addition to the locations listed in table 6, environmental monitoring is performed by U.S. Navy submarine tenders which serve as operating bases for U.S. Naval nuclear-powered submarines in Rota, Spain, and Holy Loch, Scotland. Results of the surveys in the harbor at Rota, Spain, have not shown detectable cobalt-60 in harbor bottom sediment samples. In 1965 in Holy Loch, more cobalt-60 radioactivity than expected was detected in harbor bottom sediment and on shoreline mud flat areas uncovered at low tide. However, there had been no increase of harbor water radioactivity in Holy Loch above normal background levels. Joint U.S. and British assessments of survey results confirmed that radiation levels in the vicinity of the Holy Loch anchorage were far below those which were at all likely to cause an individual to receive radiation exposure approaching limits for members of the general public. Environmental monitoring during 1970 showed radioactivity levels in Holy Loch are steadily declining and are now less than half the levels in 1965.

Summary

The total radioactivity discharged into all ports and harbors from the U.S. Naval nuclear propulsion program was 0.024 curies in 1970.

No increase of radioactivity above normal background levels has been detected in harbor water where U.S. Naval nuclear-powered ships are based, overhauled, or constructed.

Discharges of liquid wastes from U.S. Naval nuclear-powered ships have not caused a measurable increase in the general background radioactivity of the environment.

Low-level cobalt-60 radioactivity in harbor bottom sediment is detectable around a few piers at operating bases and shipyards where nuclear-powered ship maintenance and overhauls have been conducted over a period of several years. Cobalt-60 is not detectable above background levels in general harbor-bottom areas away from these piers. Maximum total radioactivity observed in a United States harbor is less than one curie of cobalt-60. Comparison to previous environmental monitoring data in references 5 through 9 shows that these environvironmental cobalt-60 levels has been steadily decreasing.

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Radiation Exposure to a Phantom Patient During Simulated Chiropractic Spinal Radiography

Jerome I. Levine,[1] *Joseph W. Howe,*[2] and *James W. Rolofson*[3]

Radiographic exposures to various organs of a simulated patient were determined for 31 techniques of spinal radiography used by doctors of chiropractic. It was determined that the radiation exposure from the most commonly used techniques would be reduced by changing to techniques using higher filtration, higher kilovoltage with reduced milliampere-seconds, and smaller beam areas. The use of split or graduated screens, step wedges, and masks also reduced radiation exposure to the simulated patient without reducing the radiographic quality of the films.

National and international organizations interested in the health and safety of the public have increasingly emphasized the need to reduce unnecessary exposure from ionizing radiation. The Federal Radiation Council (FRC) has adopted the conservative hypothesis that any exposure may have a resultant biological effect; therefore, it is axiomatic that unnecessary exposure to radiation should be avoided.

The primary goal in roentgenology is to obtain the maximum useful information with the minimum radiation exposure to patient and operating personnel consistent with the clinical objectives of the examination. Assessment of patient exposures to radiation resulting from various techniques used in chiropractic roentgenology will aid the individual chiropractor in his selection of those methods which will permit optimum diagnostic quality with minimum patient exposure.

Numerous studies have been conducted to measure the exposure to x rays resulting from various techniques commonly employed in medical diagnostic radiology (*1–7*). However, none of these studies has included the techniques employed by doctors of chiropractic.

The purpose of this study was to determine: (1) the x-ray exposure to patients at selected body and organ sites resulting from various x-ray examinations performed by the chiropractors, and (2) the possible reduction of patient exposure with the use of diverse types of x-ray accessories available to the profession.

Methods and materials

The study was performed by taking spinal radiographs of a phantom with thermoluminescent dosimeters placed at preselected sites upon the surface and within the phantom. During each of the techniques simulated, the dosimeters measured the exposure at the incident skin surface, surface of the eye, and the exit surface of the skin, and the exposure to the male and female gonads and the thyroid gland. Also evaluated were several types of x-ray beam collimators and the effect of varying total filtration in the useful beam.

For the purpose of determining the x-ray exposure, the patient was simulated by a Machlett-Alderson phantom described as an "average-size, anatomically correct man, molded of tissue-equivalent materials on a natural human skeleton" (*8*). The phantom, in addition to limited neck motion, provides universal motion at the shoulders, flexion at elbows, extension at knees, and flexion, extension, and limited abduction at the hips (*9*). In order that all radiographic films might be exposed with the phantom in an upright position, a support stand was constructed from ⅜ inch (1 cm) plywood and the phantom placed astride the stand allowing for close proximity to the upright bucky.

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Radiation exposure measurements during this study were made with lithium fluoride (LiF) powder, TLD-100[4], encapsulated in gelatin capsules. Such capsules were easily inserted into the thyroid, ovary, etc. sites of the phantom and were coded as to their site location and the exposure technique employed. Before any exposure measurements were made, a calibration of the LiF powder's sensitivity was determined throughout the energy range of interest (60 to 100 kVp).

A full-wave rectified x-ray machine capable of operation at 150 kVp and 500 mA was used as the x-ray source throughout the study. Prior to use, the machine was calibrated to accurately determine the peak kilovoltage delivered at the kV control settings. Two independent methods were used for calibration work. In the first method, a high precision resistance bank of known value was used. Measurements were repeated at 3 kV steps throughout the range of interest to obtain a calibration curve of measured kilovoltage versus indicated machine kilovoltage. The second calibration procedure, a K-edge technique described by Greening (*10*), was employed to verify the accuracy of the first calibration. Agreement for the curves was found to be within ± 3 percent for the two methods.

The x-ray tubehead was mounted with the long axis of the tube aligned parallel to the long axis of the spine. The cathode portion of the beam was directed toward the anatomic area of greatest density (i.e., the lumbar region) to take possible advantage of any "heel effect" (*11*). An upright wall-mounted 14-by 36-inch (36 by 91 cm) bucky diaphragm,[5] which incorporated a 5:1 ratio linear grid with variable speed travel, was used for all exposures throughout the study.

X-ray beam collimation for the various diagnostic radiographic field sizes needed was accomplished by the use of several types of collimators. One type offered continuous field-size adjustment with light definition of the field, making alignment and collimation exceedingly simple. This collimator incorporated an equivalent inherent filtration of approximately 3.5 mm of aluminum. Another type of collimator employed a circular indicator disc offering a selection of fixed radiographic fields corresponding to standard cassette sizes. Rotating of the disc permitted the operator to select the desired field size and obtain that coverage at a specified target-to-film distance. The dial field collimator model had a small light source for locating the central ray and alignment of the bucky tray.

An additional device, designed for full-spine radiographs, was tested on a single 14-by 36-inch (36 by 91 cm) film. This apparatus, known as the "swinging diaphragm," is attached to the tubehead and supported by its own adjustable metal legs. A spring-suspended diaphragm having separately adjustable openings for the three spinal regions is moved crosswise in front of a fixed port opening thus allowing more than one individual exposure of the spine to be made on the same film. A step-type filtration system was incorporated with the hinged covering of the port nearest the patient. The aluminum filter thicknesses were 3.51 mm for the lumbar region, 2.65 mm for the thoracic region, and 1.04 mm for the cervical region. This unit is not currently available for purchase in this country.

The following general procedure was used in obtaining the exposure measurements and exposing the films during this study. A collimator was mounted on the tubehead and the proper target-to-film distance for the diagnostic examination was selected. Proper field size selection was made, and any necessary alignments in equipment and phantom were verified. A loaded cassette was placed in the bucky tray and a correct speed setting made for grid movement. TLD capsules were placed on the phantom by means of double-sided cellophane tape at the location of the central ray entrance and exit beam, lens of the eyes, and male gonads. Dosimeter capsules were inserted into the phantom at the left and right thyroid locations and the female ovary sites.

DuPont Par Speed and Hi Speed combination intensifying screens mounted within magnesium-front, 14-by 36-inch (36 by 91 cm) cassettes were used in combination with DuPont Cronex II radiographic film.

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[4] Harshaw Chemical Co., Solid State Crystal Dept., 1945 East 97th St., Cleveland, Ohio.

[5] Universal Bucky Diaphragm Model 3650-YE, Serial No. 18705, Universal X-ray Products, Inc., Chicago, Ill.

Operating parameters and other conditions for the common techniques as well as the higher kVp techniques were provided by Dr. J. W. Howe.[6]

Exposed films were hand processed in a Bar-Ray sensitometric processing unit containing fresh Kodak liquid x-ray developers with nitrogen burst agitation. The films were developed for 5 minutes at a temperature of 68° ± 0.1°F. After 20 seconds in the stop solution, the films were placed in Kodak liquid fixer for 10 minutes, washed for 30 minutes and dried in a warm air stream. Films were identified upon development by coded numbers.

TLD capsules were read out and the exposure values in roentgens were recorded on data sheets corresponding to the diagnostic techniques and dosimeter sites.

Data and results

The exposure measurements obtained for all techniques tested are summarized in tables 1 through 3.

Table 1 presents the technical factors for each full spine AP examination used along with the corresponding exposure measurements obtained. The technical factors chosen for use with the swinging diaphragm unit in techniques 1 through 3 were suggested by Winterstein.[7] In comparing techniques 1 and 2 for the swinging diaphragm unit, it can be easily seen that technique 2 resulted in a reduction in exposure to all sites by approximately a factor of two. All factors were constant for the two methods with the single exception of increased filtration in technique 2. The final method used with the swinging diaphragm was a high kVp and reduced mAs technique which again showed significant patient exposure reduction in comparison with techniques 1 and 2.

The remaining methods listed in table 1 show the exposure values resulting from various combinations of kVp, mAs, filtration, intensifying screens and types of collimators. The lowest overall exposure values measured for a single type intensifying screen resulted from the use of the adjustable rectangular field collimator, increased filtration, and the high kVp as shown in technique number 9. Likewise, the split screen method utilizing Par Speed screens for the upper two-fifths of the film and Hi Speed screens for the lower three-fifths of the film showed the lower exposure values when the high kVp technique was used in conjunction with the same collimator and increased filtration (technique number 11).

In table 2, data are presented for AP lumbar and thoracic region film techniques. An examination of techniques 16 through 19 reveals that the high kVp method again is superior in reducing patient exposure at all locations in comparison with the "common" technique, although the eye exposures for techniques 18 and 19 were very similar.

The thoracic techniques established method 23 as the one offering the greatest reduction in patient exposure in comparison to the others described. Using the adjustable field-size collimator to narrow the field width from 14 to 8 inches (36 to 20 cm) offered a distinct reduction in exposure readings while still presenting the entire spinal column on the radiograph for diagnosis. By decreasing field size, scattered radiation to the film is theoretically reduced, which should benefit detail as well as reduce patient exposure.

From table 3 it can be established that, from the viewpoint of reduced patient exposure, technique 26 for an AP cervical spine examination is superior to the other methods described. The increased values noted in the average eye lens exposure in techniques 29 through 31 are believed to be caused by failure of the collimator used in these exposures to limit the field size to the specific limits indicated.

Table 4 indicates a comparison of the two collimators selected with a standard device, namely a Picker radiographic collimator. The data indicate that the swinging diaphragm unit and the Dial-X collimator are not accurate.

Evaluation of film quality

Film quality and detail were judged independently by Dr. J. W. Howe and two other members

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[6] Private communication from J. W. Howe, D.C. chief, Department of Roentgenology, Associates Diagnostic and Research Center, 835 Southeast Avenue, Tallmadge, Ohio 44278.

[7] Private communication from I. R. Winterstein, D.C., Department of Roentgenology, National College of Chiropractic.

Table 1. AP full spine exposure values measured at selected phantom sites during various diagnostic radiographic techniques

Technique	Total filtration[a] (mm of Al)	Type of collimator	Screen speed	kVp	mAs	All values reported in mR: Entrance exposure	Exit exposure	Average thyroid exposure	Average male gonad exposure	Average female gonad exposure	Average eye exposure
1. Swinging diaphragm	[b]3.54 [c]5.15 [d]6.01		Par	90	[b]100 [c]250 [d]300	126.6 292.5 315.9	27.6 15.4 15.4	126.7	269.2	70.6	126.6
2. Swinging diaphragm	[b]4.57 [c]6.18 [d]7.04		Par	90	[d]100 [c]250 [b]300	68.2 189.7 199.1	12.1 8.4 8.4	69.4	181.6	45.3	64.8
3. Swinging diaphragm	[b]4.57 [c]6.18 [d]7.04		Par	110	[b]10 [c]50 [d]75	13.9 63.9 78.3	1.7 3.3 5.0	16.9	85.3	26.6	6.9
4. Common[e] (one screen)	[f]4.52 [g]6.23	Dial-X[h,i]	Hi	80	200	240.4	9.8	133.8	67.1	23.8	84.9
5. High kVp (one screen)	[f]4.52 [g]6.23	Dial-X	Hi	100	60	108.8	4.6	69.4	47.2	15.5	43.1
6. High kVp (one screen)	4.52	Dial-X	Hi	100	60	129.4	3.6	70.4	104.9	30.9	45.4
7. Common[e] (one screen)	4.52	Dial-X	Hi	80	200	242.7	8.4	137.2	193.8	43.6	86.0
8. Common[e] (one screen)	7.02	Picker[k]	Hi	80	200	216.0	7.1	126.6	16.9	36.5	8.5
9. High kVp (one screen)	7.02	Picker	Hi	100	60	126.8	2.6	70.0	10.6	25.3	2.3
10. Common[e] (split screen)	7.02	Picker	Combined[m]	95	250	480.9	20.1	281.2	41.7	104.7	21.9
11. High kVp (split screen)	7.02	Picker	(m)	100	75	111.3	3.6	68.8	8.3	25.3	3.4
12. Common[e] (split screen)	[f]4.52 [g]6.23	Dial-X[i]	(m)	95	250	353.4	14.7	268.9	82.6	54.0	167.2
13. High kVp (split screen)	[f]4.52 [g]6.23	Dial-X[i]	(m)	100	75	116.5	6.7	99.7	27.1	18.1	55.2
14. High kVp (split screen)	4.52	Dial-X[i]	(m)	100	75	176.8	10.8	105.9	153.6	44.1	63.9
15. Common[e] (split screen)	4.52	Dial-X[i]	(m)	95	250	484.3	26.0	299.3	440.2	115.5	176.7

[a] Includes 1 mm aluminum equivalent filtration from x-ray tube.
[b] Cervical.
[c] Thoracic.
[d] Lumbar.
[e] Technique used by the majority of chiropractors as determined by Dr. J. W. Howe.
[f] Upper 1/3 of beam.
[g] Lower 2/3 of beam.
[h] Dial-X Collimator Model DM; Dial-X Instruments, Inc., 331 W. Merrick Road, Valley Stream, N.Y. (Serial No. 3133).
[i] 14- by 36-inch (36 by 91 cm) field. Field size as listed by manufacturer.
[k] Picker Radiographic Collimator; Delux Model 2089, Picker X-ray Company, White Plains, N.Y.
[m] Upper 2/5's of screen—Par; lower 3/5's of screen—Hi.

Table 2. AP regional spine exposure values measured at selected phantom sites during various diagnostic radiographic techniques

Technique	Total filtration[a] (mm of Al)	Type of collimator	Screen speed	kVp	mAs	Field size (inches)[b]	All values reported in mR: Entrance exposure	Exit exposure	Average thyroid exposure	Average male gonad exposure	Average female gonad exposure	Average eye exposure
16. Common[c] lumbar	4.52	Dial-X[d]	Par	85	100	14 by 17	745.7	21.5	9.2	36.8	133.8	5.7
17. High kVp lumbar	4.52	Dial-X	Par	110	10	14 by 17	132.2	6.7	2.0	9.5	32.2	1.4
18. High kVp lumbar	7.02	Picker[e]	Par	110	10	14 by 17	166.1	4.4	.8	3.5	30.3	.6
19. Common[c] lumbar	7.02	Picker	Par	85	100	11 by 14	841.3	16.0	2.3	6.4	104.6	.5
20. Common[c] thoracic	4.52	Dial-X	Par	75	50	14 by 17	176.2	4.5	26.7	1.8	5.4	2.7
21. DuPont thoracic (*12*)	4.52	Dial-X	Par	90	100	14 by 17	837.9	32.7	137.0	11.5	33.9	11.9
22. High kVp thoracic	4.52	Dial-X	Par	100	15	14 by 17	171.6	(f)	30.5	2.0	7.8	2.3
23. High kVp thoracic	7.02	Picker	Par	100	15	8 by 17 field (14 by 17 film)	184.5	4.1	3.4	ND	2.5	ND
24. DuPont thoracic (*12*)	7.02	Picker	Par	90	100	8 by 17 field (14 by 17 film)	882.7	21.5	19.9	3.9	12.4	4.0
25. Common[c] thoracic	7.02	Picker	Par	75	50	8 by 17 field (14 by 17 film)	201.3	4.5	4.5	1.7	3.3	1.7

[a] Includes 1 mm aluminum equivalent filtration from x-ray tube.
[b] 14 by 17 inches = 36 by 43 cm; 11 by 14 inches = 28 by 36 cm; 8 by 17 inches = 20 by 43 cm. Field size as listed by manufacturer.
[c] Technique used by the majority of chiropractors as determined by Dr. J. W. Howe.
[d] Dial-X Collimator Model DM; Dial-X Instruments, Inc., 331 W. Merrick Road, Valley Stream, N.Y. (Serial No. 3133).
[e] Picker Radiographic Collimator; Delux Model 2089, Picker X-ray Company, White Plains, N.Y.
[f] Measurement unavailable—capsule came open and powder lost during study.
ND, nondetectable.

Table 3. AP cervical spine exposure values measured at selected phantom sites during various diagnostic radiographic techniques

Technique	Total filtration[a] (mm of Al)	Type of collimator	Screen speed	kVp	mAs	Field size (inches)[b]	All values reported in mR					
							Entrance exposure	Exit exposure	Average thyroid exposure	Average male gonad exposure	Average female gonad exposure	Average eye exposure
26. High kVp cervical	7.02	Picker	Par	84	10	8 by 10	57.3	4.5	45.7	ND	ND	4.2
27. DuPont cervical (*12*)	7.02	Picker	Par	70	40	8 by 10	157.6	7.7	102.5	0.5	ND	8.2
28. Common[c] cervical	7.02	Picker	Par	60	50	8 by 10	103.9	4.3	74.4	ND	0.3	5.7
29. High kVp cervical	4.52	Dial-X	Par	84	10	8 by 10	56.3	4.2	45.9	ND	[illegible]	[d]47.5
30. DuPont cervical (*12*)	4.52	Dial-X	Par	70	40	8 by 10	139.8	6.8	103.2	ND	.4	[d]119.5
31. Common[c] cervical	4.52	Dial-X	Par	60	50	8 by 10	100.0	5.5	71.5	.4	.3	[d]65.3

[a] Includes 1 mm aluminum equivalent filtration from x-ray tube.

[b] 8 by 10 inches = 20 by 25 cm. Field size as listed by manufacturer.

[c] Technique used by the majority of chiropractors as determined by Dr. J. W. Howe.

[d] These high readings of average exposure to lens of eye must be due to the oversized field of the Dial-X collimator (see table 4). Entrance beam was aligned at same place on the phantom for each collimator. Evidently, the Picker collimator is much more exact in defining field size.

ND, nondetectable.

Table 4. Field size for various types of x-ray collimators

Collimator or beam-limiting device	Field size as listed by manufacturer (inches)	Target to film distance for listed field size (inches)	Field size measured (Polaroid film) (inches)	Target to film distance for measured field size (inches)	Excess beam area (inches²)	Percent error[a]
1. Swinging diaphragm unit	None listed by manufacturer—unit designed for use in full spine radiographs, i.e., 14 by 36 film (36 by 91 cm)	96 (244 cm)	24 by 51.5 (61 by 131 cm)	96 (244 cm)	732 (4,740 cm²)	145
2. Dial-X collimator	14 by 36 (36 by 91 cm)	60 (152 cm)	17.5 by 38 (44.5 by 97 cm)	60 (152 cm)	161 (1,040 cm²)	32
	14 by 36 (36 by 91 cm)		21.5 by 45.25 (54.7 by 115 cm)	72 (183 cm)	469 (3,030 cm²)	93
	14 by 17 (36 by 43 cm)	36 (91 cm)	17.25 by 19.75 (44 by 50 cm)	36 (91 cm)	103 (665 cm²)	42
	14 by 17 (36 by 43 cm)		19.5 by 22.25 (49.6 by 56.6 cm)	40 (102 cm)	196 (1,270 cm²)	82
	8 by 10 (20 by 25 cm)	36 (91 cm)	9.5 by 12 (24.2 by 30.5 cm)	36 (91 cm)	34 (220 cm²)	43
	8 by 10 (20 by 25 cm)		10.75 by 13.75 (27.3 by 35 cm)	40 (102 cm)	67.8 (438 cm²)	85
3. Picker radiographic collimator	14 by 17 (36 by 43 cm)	72 (183 cm)	13.8 by 17.1 (35 by 43 cm)	72 (183 cm)	−2.02 (−13 cm²)	−.01
	8 by 17 (20 by 43 cm)		8 by 17.1 (20 by 43 cm)		.8 (5 cm²)	.01

[a] Excess beam area to standard beam area (area of field size as listed by manufacturer).

of the chiropractic profession. The phantom offered inherent problems which affected film quality since the jointed arrangement that allowed limited mobility of the neck offered far different radiopacity than the surrounding tissues, and the mediastinal area was considerably different in its characteristics than what would be encountered in the human body. Other differences in the phantom as compared to a human subject make the films produced in this study less than optimum so that estimates regarding quality and detail could only be considered roughly equivalent to those which would be present on radiographic films of the human subject. A further limitation, the use of a 5:1 ratio in the bucky grid, made film quality less than optimum. The American College of Chiropractic Roentgenologists has long recommended a minimum of 8:1 grid ratio for spinal radiography.

With these factors considered, judgment of film quality and detail showed the best full spine radiographs to have been produced by techniques 2, 11, and 13; with 9 and 4 next best; 1, 5, 6, 7, 8, and 14 were judged acceptable; while 3 was not sufficiently dense to be of diagnostic value; and techniques 10, 12, and 15 produced radiographs which were entirely too dense for evaluation.

In none of the full spine films was the cervical region adequately portrayed due to the variation in radiopacity inherent in the phantom. The best cervical visualizations were in techniques 2, 11, and 13. The regional films of the cervical area were also of poor quality and were generally comparable to the full spine studies of the cervical region in detail. Film quality and detail were not remarkably enhanced in the regional films of the thoracic or lumbar areas as compared to the same areas viewed on the full spine radiographs. There was some improvement in detail in the films where collimation limited the exposed area to a smaller field than the film size.

The use of split screens as compared to a uniform speed screen did seem to enhance film quality sufficiently to make their use worthwhile. The abrupt change from slow screen to fast was objectionable. There are now available "proportioned" or "graduated" screens which increase in speed from one end to the other without the sharp change seen in the split screens. These were not employed in this study, but would seem preferable to the abrupt transition of the split screen.

Step wedges were employed in techniques 4, 5, 12, and 13. These did help slightly to enhance radiographic quality, but the difference between techniques 2, 11, and 13 was not really significant. Technique 2 employed the swinging diaphragm with uniform par speed screens and moderately high kVp. Technique 11 employed the variable collimator with split screens, extra filtration, and high kilovoltage. Technique 13 utilized the Dial-X collimator with step wedges, split screens, and high kilovoltage. The practical difference in film quality among the three was negligible. The ability to select the proper technique for each region with the swinging diaphragm made this equivalent to the split screen and step wedge combination.

We can conclude from judgment of film quality that with certain reservations, a properly exposed 14-by 36-inch (36 by 91 cm) film utilizing a 72 inch (183 cm) or greater target-to-film distance (TFD) will give roughly as good film quality as will regional films of any spinal regions. The factor of radiographic distortion, though, makes regional films more valuable for specific information regarding a particular area, although if an 84 inch (210 cm) or greater TFD is used, the angle of incidence of the x rays is equal to or less than the angle of incidence used for a 14- by 17-inch (36 by 43 cm) film at a 40 inch (100 cm) TFD.

Taking technique 2 for a basis and comparing it with techniques 18, 23, and 26 for regional AP films of cervical, lumbar and thoracic areas, we see that there is only slightly less of an entrance exposure for the regional films than for the full spine, while the thyroid dose is lower combining techniques 18, 23, and 26 than in techniques 2, 11, or 13.

The exposure to the male gonads for techniques 18, 23, and 26 totals 3.5 mR which compares favorably with the 8.3 mR seen in technique 11. The fact that there is a much higher male gonadal exposure in techniques 2 and 13 indicates that collimation was not as sharp under these two techniques as by use of a variable collimator. The female gonadal exposure by combining techniques 18, 23, and 26 totals 32.8 mR, which is higher than was seen in techniques 11 or 13 and lower than that seen in technique 2. The eye exposure from combining techniques 18, 23, and 26 totals 4.8 mR which again is slightly more that was present in technique 11, with the greater differences in techniques 2 and 13 again reflecting the less adequate collimation employed. From these findings we can conclude that there is not appreciably more radiation to selected organ sites of the patients in a full spine film using high kilovoltage, low milliamperage techniques and adequate collimation and filtration than would be present from AP regional films using a similar high kVp, low mA, diagnostic radiographic procedure.

Conclusions

It is clear that some of the commonly used techniques, such as those used in this study and in reference (*12*), do give excess radiation factors as well as excessive film density which yields less than optimum film quality. There is a considerable need for further studies and efforts toward obtaining optimum quality radiographs with less patient exposure. Considering the radiation exposure of the various critical areas, film quality, and detail available, it is conclusive that diagnostic quality does not suffer as compared to techniques in common usage through utilizing

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those technical factors which produce the least patient exposure. Sharp collimation, high filtration, and use of split or graduated screens where applicable are surely of great value. If a step wedge arrangement could be attached to a variable collimator, and masks or similar devices used to further restrict the beam from areas where there is no clinical interest, there would unquestionably be further enhancement of radiographic quality and a further decrease in radiation exposure to the patient.

Summary

The data presented in this study show that patient exposures received during diagnostic spinal examinations can vary significantly depending on the radiographic technique used.

The study indicates that increasing the amount of filtration, using an adjustable rectangular collimator with a beam-defining light, and raising the voltage coupled with an appropriate reduction in amperage-time are extremely helpful in reducing patient x-ray exposure. Collimating the beam to the smallest possible dimension that encompasses the spinal column will also reduce exposure to the patient.

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Data

SECTION I. MILK AND FOOD

Milk Surveillance, January 1971

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption can be readily obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Office of Radiation Programs, Environmental Protection Agency, and the Office of Food Sanitation, Food and Drug Administration, U.S. Public Health Service, consists of 63 sampling stations; 61 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State Health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiological Health Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Environmental Protection Agency)—5 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations

The sampling locations that make up the networks presently reporting in *Radiological Health Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that are formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of

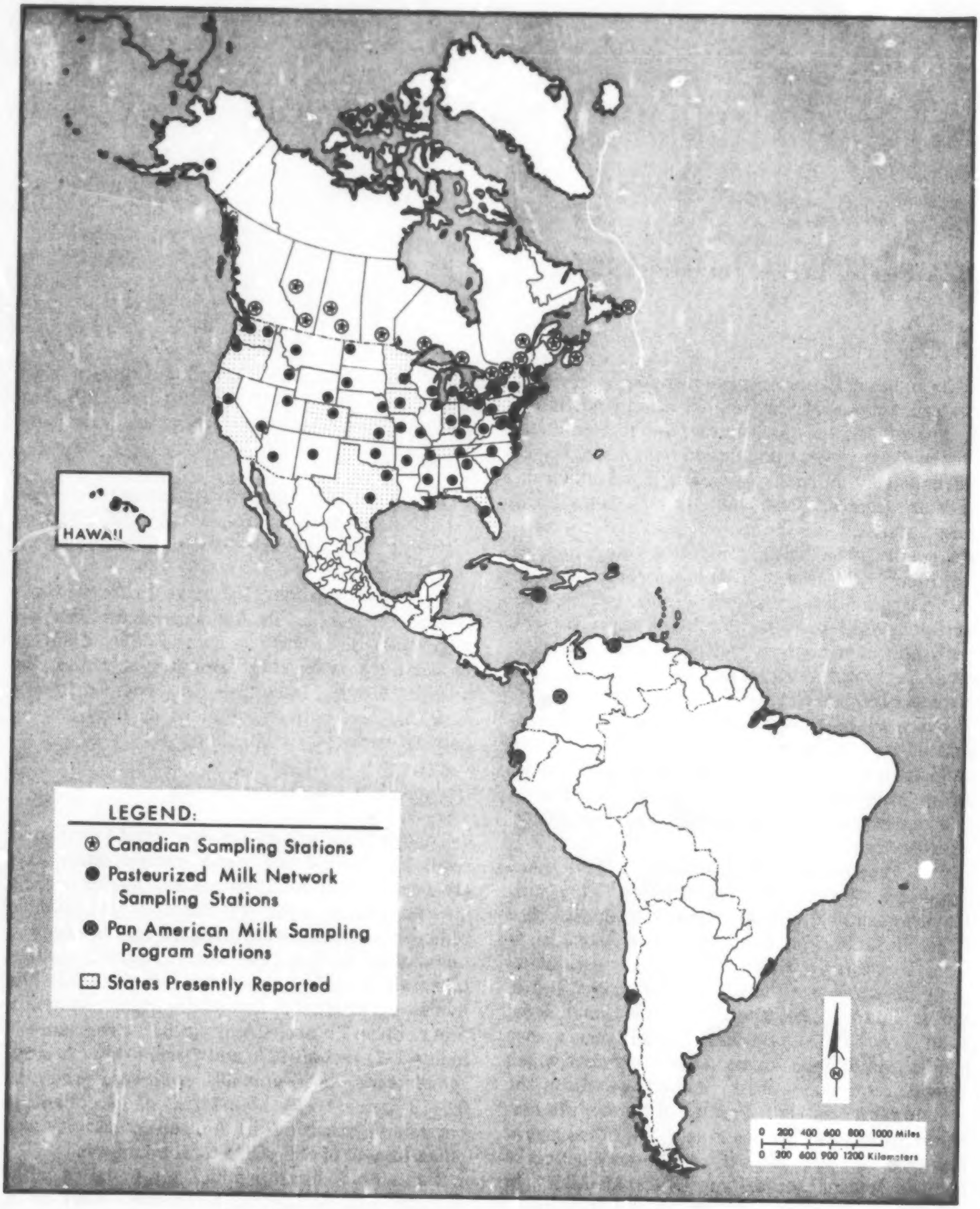
HAWAII
LEGEND:
Canadian Sampling Stations
Pasteurized Milk Network Sampling Stations
Pan American Milk Sampling Program Stations
States Presently Reported
0 200 400 600 800 1000 Miles
0 300 600 900 1200 Kilometers
N

Figure 1. Milk sampling networks in the Western Hemisphere

metabolically similar radionuclides (radiostrontium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variations, expressed in terms of 2 standard deviations (2σ), for these elements are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for May 1963–March 1966 (*3*) and were determined for use in general radiological health calculations or discussions.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Office of Radiation Programs conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested radiochemical laboratories. The generalized procedure for making such a study has been outlined previously (*4*).

The most recent study was conducted during May–July 1970, with 28 laboratories participating in an experiment on milk samples containing known concentrations of strontium-89, strontium-90, iodine-131, cesium-137, and barium-140 (*5*). Of the 20 laboratories producing data for the networks reporting in *Radiological Health Data and Reports*, 13 participated in the experiment.

The accuracy results of this experiment are shown in table 1. In general, considerable improvement is needed, especially in the accuracy measurements. These possible differences should be kept in mind when considering the integration of data from the various networks.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methods, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic procedures. The methods used by each of the networks have been

Table 1. Distribution of mean results, quality control experiment

Isotope and known concentration		Number of laboratories in each category			
		Acceptable[a]	Warning level[b]	Unacceptable[c]	Total
Strontium 89:	High (258 pCi/liter)	7 (44%)	1 (6%)	8 (50%)	16
	Low (15 pCi/liter)	11 (69%)	3 (19%)	2 (12%)	16
Strontium-90:	Intermediate (79.4 pCi/liter)	13 (57%)	4 (17%)	6 (26%)	23
	Low (32.0 pCi/liter)	5 (25%)	4 (20%)	11 (55%)	20
Iodine-131:	High (507 pCi/liter)	18 (67%)	2 (7%)	7 (26%)	27
	Low (49 pCi/liter)	16 (64%)	3 (12%)	6 (24%)	25
Cesium-137:	High (259 pCi/liter)	20 (74%)	3 (11%)	4 (15%)	27
	Low (53 pCi/liter)	17 (65%)	5 (19%)	4 (15%)	26
Barium-140:	High (302 pCi/liter)	18 (67%)	2 (7%)	7 (26%)	27
	Low (33 pCi/liter)	23 (92%)	0	2 (8%)	25

[a] Measured concentration less than or equal to 2σ of the known concentration.
[b] Measured concentration greater than 2σ and less than or equal to 3σ of the known concentration.
[c] Measured concentration greater than 3σ of the known concentration.

referenced in earlier reports appearing in *Radiological Health Data and Reports.*

A previous article (*6*) summarized the criteria used by the State networks in setting up their milk sampling activities and their sample collection procedures as determined during a 1965 survey. This reference and an earlier data article for the particular network of interest may be consulted should events require a more definitive analysis of milk production and milk consumption coverage afforded by a specific network.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. Many networks are analyzing composite samples on a quarterly basis for certain nuclides. The frequency of collection and analysis varies not only among the networks but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short periods of time, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and is generally increased at the first measurement or recognition of a new influx of this radionuclide.

The data presentation (table 2) also reflects whether raw or pasteurized milk was collected. An analysis of raw and pasteurized milk samples collected during January 1964 to June 1966 indicated that, for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant (*7*). Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard deviation counting errors or 2-standard deviation total analytical errors from replicate analyses (*3*). The practical reporting level reflects analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below these practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical error or precision expressed as pCi/liter or percent in a given concentration range have also been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2-standard deviations)
Strontium-89	1–5 pCi/liter for levels <50 pCi/liter; 5–10% for levels ≥50 pCi/liter
Strontium-90	1–2 pCi/liter for levels <20 pCi/liter; 4–10% for levels ≥20 pCi/liter
Iodine-131 Cesium-137 Barium-140	4–10 pCi/liter for levels <100 pCi/liter; 4–10% for levels ≥100 pCi/liter.

For iodine-131, cesium-137, and barium-140, there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Table 2. Concentration of radionuclides in milk for January 1971 and 12-month period, February 1970 through January 1971

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average[c]	Monthly average[b]	12-month average
UNITED STATES:								
Ala:	Montgomery[c]	P	4	6	0	0	13	8
Alaska:	Palmer[c]	P	3	6	0	0	16	10
Ariz:	Phoenix[c]	P	0	1	0	0	0	0
Ark:	Little Rock[c]	P	14	13	0	0	0	13
Calif:	Sacramento[c]	P	0	2	0	0	0	0
	San Francisco[c]	P	0	2	0	0	0	0
	Del Norte	P	16	17	0	0	10	14
	Fresno	P	[illegible]	2	0	0	0	1
	Humboldt	P	5	5	0	0	2	5
	Los Angeles	P	3	2	0	0	0	0
	Mendocino	P	5	3	0	0	4	2
	Sacramento	P	3	3	0	0	3	1
	San Diego	P	2	2	0	0	0	0
	Santa Clara	P	2	2	0	0	0	1
	Shasta	P	2	3	0	0	3	2
	Sonoma	P	3	3	0	0	1	1
Colo:	Denver[c]	P	3 (2)	5	0 (2)	0	11 (2)	1
	West	R	(d)		NS	[e]1	NS	[e]4
	Northeast	R	(d)		[e]0 (5)	[e]0	[e]0 (5)	[e]0
	East	R	(d)		[e]0 (2)	[e]0	[e]0 (2)	[e]0
	Southeast	R	(d)		NS	[e]0	NS	[e]0
	South Central	R	(d)		NS	NS	NS	NS
	Southwest	R	(d)		[e]0	[e]0	[e]0	[e]4
	Northwest	R	(d)		NS	[e]5	NS	[e]0
Conn:	Hartford[c]	P	8	7	0	0	17	12
	Central	P	7	7	0	0	23	16
Del:	Wilmington[c]	P	8	9	0	0	13	8
D.C:	Washington[c]	P	7	7	0	0	0	7
Fla:	Tampa[c]	P	5	5	0	0	40	50
	West	R	6	6	0	0	24	48
	North	R	4	10	0	0	12	26
	Northeast	R	7	6	0	0	21	39
	Central	R	NS	7	0	1	24	48
	Tampa Bay area	R	7	6	0	0	39	50
	Southeast	R	11	9	0	0	74	76
Ga:	Atlanta[c]	P	11	11	0	0	16	14
Hawaii:	Honolulu[c]	P	4	2	0	0	0	0
Idaho:	Idaho Falls[c]	P	4	5	0	0	17	7
Ill:	Chicago[c]	P	7	7	0	0	0	10
Ind:	Indianapolis[c]	P	6	8	0	0	12	6
	Northeast	P	8	10	0	0	10	12
	Southeast	P	10	11	0	0	15	12
	Central	P	8	9	0	5	10	10
	Southwest	P	13	12	0	0	10	10
	Northwest	P	10	11	0	0	10	12
Iowa:	Des Moines[c]	P	5	6	0	0	12	3
	Iowa City	P	8	8	0	0	19	14
	Des Moines	P	7	8	0 (4)	0	13 (4)	9
	Spencer	P	4	5	0	0	12	8
	Fredericksburg	P	NS	NS	NS	NS	NS	NS
Kans:	Wichita[c]	P	7	8	0	0	0	3
	Coffeyville	P	8	9	0	2	0	2
	Dodge City	P	5	7	0	0	0	1
	Falls City	R	11	14	0	3	12	6
	Hays	P	12	13	0	2	0	1
	Kansas City	P	9	8	0	0	12	5
	Topeka	P	9	10	0	2	21	6
	Wichita	P	10	12	0	0	11	1
Ky:	Louisville[c]	P	8	9	0	0	0	4
La:	New Orleans[c]	P	16	14	0	0	26	19
Maine:	Portland[c]	P	9	10	0	0	15	22
Md:	Baltimore[c]	P	9	8	0	0	16	8
Mass:	Boston[c]	P	9	10	0	0	23	21
Mich:	Detroit[c]	P	7	8	0	0	12	9
	Grand Rapids	P	7	9	0	0	18	13
	Bay City	P	NS	7	[e]0	[e]0	14	11
	Charlevoix	P	11	12	[e]0 (2)	[e]1	7 (2)	15
	Detroit	P	6	8	[e]0	[e]0	[illegible]	8
	Grand Rapids	P	8	9	[e]0	[e]0	[illegible]	7
	Lansing	P	8	9	[e]0 (2)	[e]0	15 (2)	14
	Marquette	P	13	14	[e]0 (2)	[e]0	21 (2)	23
	Monroe	P	5	6	[e]0 (2)	[e]0	0 (2)	3
	South Haven	P	8	8	[e]0 (3)	[e]0	4 (3)	6
Minn:	Minneapolis[c]	P	9	9	0	0	11	11
	Bemidji	P	8	8	0	0	21	20
	Mankato	P	5	4	0	0	0	0
	Rochester	P	6	6	0	0	0	11
	Duluth	P	11	13	0	0	22	27
	Worthington	P	6	[illegible]	0	0	0	0

See footnotes at end of table.

Table 2. Concentration of radionuclides in milk for January 1971 and 12-month period, February 1970 through January 1971—Continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES—Continued								
Minn:	Minneapolis	P	20	10	0	0	17	16
	Fergus Falls	P	6	5	0	0	11	13
	Little Falls	P	9	11	0	0	0	34
Miss:	Jackson[c]	P	9	11	0	0	0	11
Mo:	Kansas City[c]	P	6	8	0	0	0	2
	St. Louis[c]	P	7	8	0	0	12	5
Mont:	Helena[c]	P	4	5	0	0	14	8
Nebr:	Omaha[c]	P	NA	5	0	0	0	1
Nev:	Las Vegas[c]	P	0	2	0	0	0	0
N.H:	Manchester[c]	P	9	9	0	0	22	20
N.J:	Trenton[c]	P	7	7	0	0	15	10
N.Mex:	Albuquerque[c]	P	3	3	0	0	0	0
N.Y:	Buffalo[c]	P	7	7	0	0	14	11
	New York City[c]	P	9	10	0	0	16	18
	Syracuse[c]	P	7	7	0	0	0	9
	Albany	P	11	7	0 (4)	0	21 (4)	0
	Messena	P	10	8	0 (2)	0	26 (2)	22
	Newburg	P	8	7	0 (3)	0	0 (4)	0
	New York City	P	[d]0	8	0	0	0	0
	Syracuse	P	6	4	0 (2)	0	0 (2)	0
N.C:	Charlotte[c]	P	10	11	0	0	14	13
N.Dak:	Minot[c]	P	9	10	0	0	0	11
Ohio:	Cincinnati[c]	P	8	7	0	0	12	4
	Cleveland[c]	P	7	8	0	0	12	12
Okla:	Oklahoma City[c]	P	NA	7	0	0	13	6
Oreg:	Portland[c]	P	4	6	0	0	0	5
	Baker	P	NA	4	[d]0	[d]0	0	6
	Coos Bay	P	6	6	[d]0	[d]0	0	11
	Eugene	P	2	2	[d]0	[d]0	0	3
	Medford	P	2	3	[d]0	[d]0	0	8
	Portland composite	P	3	5	[d]0	[d]0	0	7
	Portland local	P	4	5	[d]0	[d]0	0 (2)	6
	Redmond	P	NA	4	[d]0	[d]0	0	0
	Tillamook	R	NA	8	[d]0	[d]0	16	16
Pa:	Philadelphia[c]	P	NS	9	NS	0	NS	7
	Pittsburgh[c]	P	11	11	0	0	17	14
	Dauphin	P	7	8	1	2	17	10
	Erie	P	NS	12	NS	1	24	26
	Philadelphia	P	NS	8	NS	0	24	15
	Pittsburgh	P	8	13	0	1	18	20
S.C:	Charleston[c]	P	11	10	0	1	12	18
S.Dak:	Rapid City[c]	P	7	7	0	0	0	4
Tenn:	Chattanooga[c]	P	8	9	0	0	0	9
	Memphis[c]	P	7	9	0	0	15	7
	Chattanooga	P	8	9	0	0	17	14
	Clinton	P	9	11	0	0	12	14
	Fayetteville	P	6	6	0 (2)	0	6 (2)	10
	Knoxville	P	9	11	0	0	18	14
	Nashville	P	6	7	0 (3)	0	12 (3)	12
Tex:	Austin[c]	P	0	2	0	0	0	2
	Dallas[c]	P	4	7	0	0	0	7
	Amarillo	R	NA	5	NA	0	NA	5
	Corpus Christi	R	NA	4	NA	0	NA	0
	El Paso	R	NA	3	NA	0	NA	2
	Fort Worth	R	4	5	0	0	0	0
	Harlingen	R	NA	2	NA	0	NA	14
	Houston	R	6	6	0	0	15	0
	Lubbock	R	NA	3	NA	0	NA	0
	Midland	R	3	2	0	0	0	0
	San Antonio	R	NA	4	NA	0	NA	0
	Texarkana	R	NA	8	NA	0	NA	0
	Tyler	R	19	16	0	0	20	18
	Uvalde	R	NA	2	NA	0	NA	0
	Wichita Falls	R	NA	4	NA	0	NA	2
Utah:	Salt Lake City[c]	P	4	4	0	0	14	9
Vt:	Burlington[c]	P	6	8	0	0	14	14
Va:	Norfolk[c]	P	9	9	0	0	12	9
Wash:	Seattle[c]	P	5	6	0	0	0	3
	Spokane[c]	P	6	5	0	0	0	2
	Benton County	R	0	0	0	0	[d]0	2
	Franklin County	R	7	3	0	0	[d]0	5
	Sandpoint, Idaho	R	13	11	0	0	23	21
	Skagit County	R	6	6	0	0	15	10
W.Va:	Charleston[c]	P	4	8	0	0	13	6
Wisc:	Milwaukee[c]	P	6	6	0	0	17	12
Wyo:	Laramie[c]	P	4	5	0	0	0	1

See footnotes at end of table.

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Table 2. Concentration of radionuclides in milk for January 1971 and 12-month period, February 1970 through January 1971—Continued

Sampling location	Type of sample[a]	Radionuclide concentration (pCi/liter)					
		Strontium-90		Iodine-131		Cesium-137	
		Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
CANADA:							
Alberta: Calgary	P	NA		NA		17	17
Edmonton	P	NA		NA		24	20
British Columbia:							
Vancouver	P	NA		NA		16	24
Manitoba:							
Winnipeg	P	NA		NA		21	24
New Brunswick:							
Fredericton	P	NA		NA		28	24
Newfoundland:							
St. John's	P	NA		NA		19	34
Nova Scotia:							
Halifax	P	NA		NA		16	22
Ontario: Ft. William	P	NA		NA		18	15
Ottawa	P	NA		NA		28	33
Sault Ste. Marie	P	NA		NA		28	35
Toronto	P	NA		NA		11	10
Windsor	P	NA		NA		6	10
Quebec: Montreal	P	NA		NA		15	18
Quebec	P	NA		NA		28	28
Saskatchewan:							
Regina	P	NA		NA		14	14
Saskatoon	P	NA		NA		13	16
CENTRAL AND SOUTH AMERICA:							
Colombia:							
Bogota	P	0	0	0	0	0	0
Chile: Santiago	P	0	0	0	0	0	0
Ecuador: Guayaquil	P	0	0	0	0	0	0
Jamaica: Montego Bay	P	NS	5	NS	0	NS	31
Venezuela:							
Caracas	P	0	1	0	0	0	0
Canal Zone:							
Cristobal[c]	P	3	1	0	0	14	10
Puerto Rico:							
San Juan[c]	P	4	4	0	0	12	7
PMN Network average[f]		6	7	0	0	10	9

[a] P, pasteurized milk.
R, raw milk.

[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a monthly period, the number of samples in the monthly average is given in parentheses.

[c] Pasteurized Milk Network station. All other sampling locations are part of the State or National network.

[d] Radionuclide analysis not routinely performed.

[e] The practical reporting levels for these networks differ from the general ones given in the text. Sampling results for the networks were equal to or less than the following practical reporting levels:

Iodine-131: Colorado—25 pCi/liter
Michigan—14 pCi/liter
Oregon—15 pCi/liter

Cesium-137: Colorado—25 pCi/liter
New York—20 pCi/liter
Oregon—15 pCi/liter

Strontium-90: New York—3 pCi/liter

[f] This entry gives the average radionuclides concentrations for the PMN stations denoted by footnote [c].
NA, no analysis.
NS, no sample collected.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the U.S. data on radioactivity in milk presented in *Radiological Health Data and Reports* in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions was presented in the December 1970 issue of *Radiological Health Data and Reports.*

Data reporting format

Table 2 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are routinely reported to *Radiological Health Data and Reports.* The relationship between the PMN stations and the State stations is shown in figure 2. The first column under each of the reported radionuclides gives the monthly average

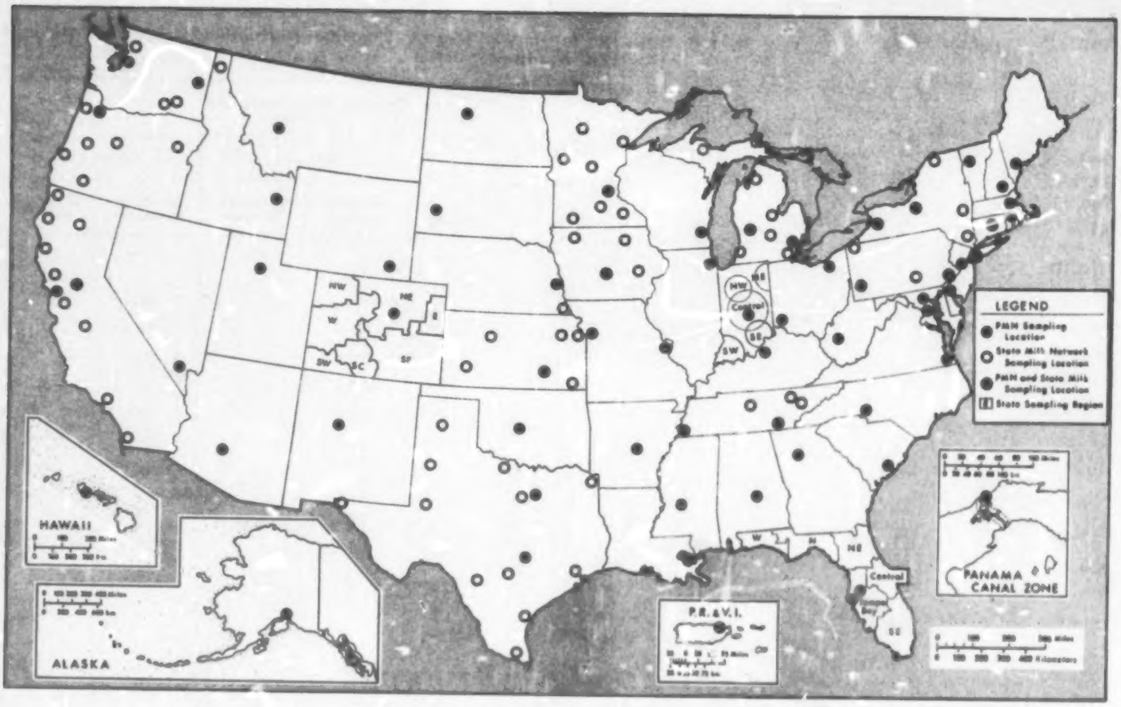

Figure 2. State and PMN milk sampling locations in the United States

for the station and in parentheses the number of samples analyzed in that month. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed populations groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 2, surveillance results are given for strontium-90, iodine-131, and cesium-137 for January 1971 and the 12-month period, February 1970 through January 1971. Except where noted, the monthly average represents a single sample for the sampling station. Strontium-89 and barium-140 data have been omitted from table 2 since levels at the great majority of the stations for January 1971 were below the respective practical reporting levels. The following station average reflects a sample in which strontium-89 was detected: Kans., Wichita (State), 6 pCi/liter; Colombia, Bogota, 5 pCi/liter.

Iodine-131 results are included in the table, even though they were generally below practical reporting levels. Because of the lower guide levels established by the Federal Radiation Council, levels in milk for this radionuclide are of particular public health interest. In general, the practical reporting level for iodine-131 is numerically equal to the upper value of Range I (10 pCi/liter) of the FRC radiation protection guide.

Strontium-90 monthly averages ranged from 0 to 20 pCi/liter in the United States for January 1971, and the highest 12-month average was 17 pCi/liter (Del Norte, Calif.) representing 8.5 percent of the Federal Radiation Council radiation protection guide. Cesium-137 monthly averages ranged from 0 to 74 pCi/liter in the United States for January 1971, and the highest 12-month average was 76 pCi/liter (Southeast Florida), representing 2.1 percent of the value derived from the recommendations given in the Federal Radiation Council report. Of particular interest are the consistently higher cesium-137 levels that have been observed in Florida (*8*) and Jamaica. Iodine-131 results for individual samples were all below the practical reporting level, with the exception of Dauphin, Pa.(State), 11 pCi/liter.

Acknowledgement

Appreciation is expressed to the personnel of the following agencies who provide data for their milk surveillance networks:

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Radiation Protection Division
Canadian Department of National
Health and Welfare

Radiological Health Section
Division of Occupational and
Radiological Health
Colorado Department of Health

Radiological Health Services
Division of Medical Services
Connecticut State Department of Health

Radiological and Occupational
Health Section
Department of Health and
Rehabilitative Services
State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiation Control Section
Environmental Health Division
Kansas State Department of Health

Radiological Health Services
Division of Occupational Health
Michigan Department of Health

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Nuclear Engineering
New York State Department of
Environmental Conservation

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Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Radiation Control Section
Division of Health
Washington Department of
Social and Health Service

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Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs reported in *Radiological Health Data and Reports* are as follows:

Program	Period reported	Issue
California Diet Study	January–June 1970	November 1970
Carbon-14 in Total Diet and Milk	July–December 1970	May 1971
Connecticut Standard Diet	July–December 1969	December 1970
Institutional Diet Samples	October–December 1970 and Annual summary 1970	May 1971
Strontium-90 in Tri-City Diets	January–December 1969	June 1970

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Carbon-14 in Total Diet and Milk, July-December 1970

Office of Radiation Programs
Environmental Protection Agency

In July 1965, a program to determine the levels of carbon-14 and tritium in the total diet and milk in the United States was initiated. In December 1970, this program was transferred to the Radiation Office, (now the Office of Radiation Programs) of the Environmental Protection Agency (EPA). Initially, monthly samples from each of the EPA Institutional Total Diet Sampling Network (ITDSN) and Pasteurized Milk Network (PMN) stations were composited and analyzed according to six arbitrarily selected regions: Northeast, South, Delta, Central, Southwest, and Northwest. Figure 1 shows the ITDSN and PMN sampling stations in each of the designated regions.

In January 1966, the program was modified to include selected stations in each of the previously mentioned regions plus Alaska and Hawaii. The nine geographically distributed sampling stations are: Palmer, Alaska; Honolulu, Hawaii; Idaho Falls, Idaho; Chicago, Ill; New Orleans, La; Boston, Mass; Portland, Oreg; and Charleston, S.C. Los Angeles, Calif. is not a PMN station, but a special milk sample is collected for purposes of comparison with the routine ITDSN sample.

A 1-liter milk sample and a 2-kilogram food sample are sent to the Public Health Service's Northeastern Radiological Health Laboratory for analysis. The milk and total diet samples analyzed represent the samples collected for that month.

The carbon-14 analyses are performed semi-annually. The tritium analyses were discontinued in July 1969 because the results were only slightly above the limit of detectability and were less

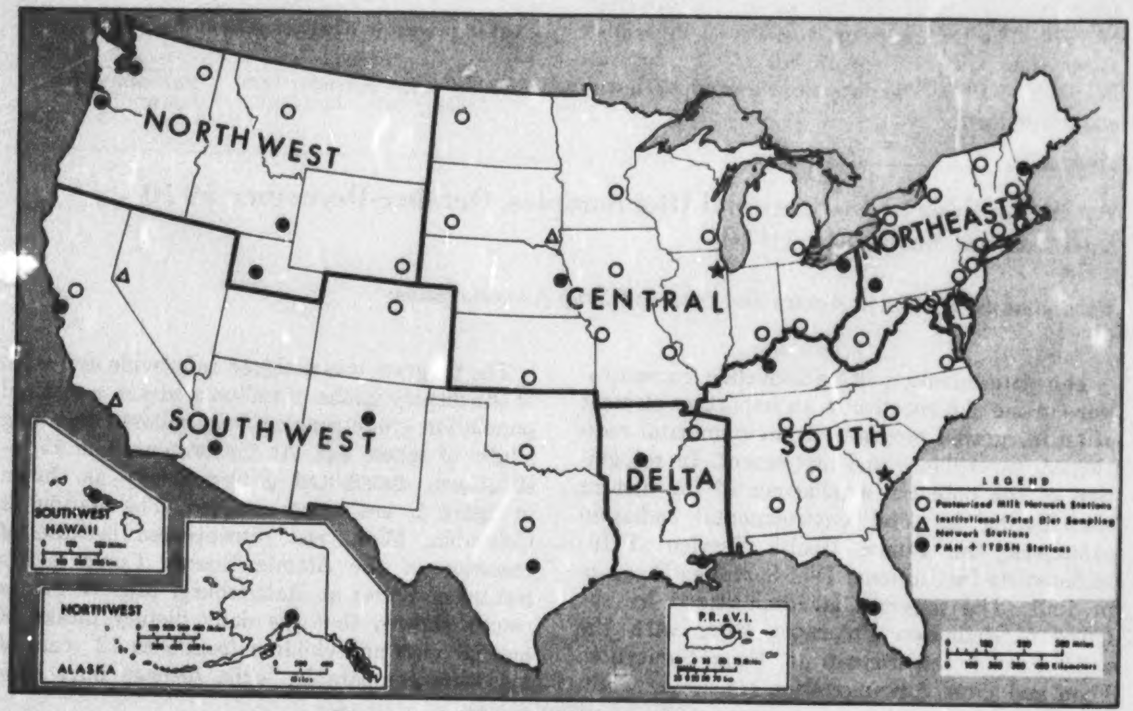
NORTHWEST
CENTRAL
NORTHEAST
SOUTHWEST
DELTA
SOUTH
SOUTHWEST
HAWAII
NORTHWEST
ALASKA
P.R.&V.I.
LEGEND
Pasteurized Milk Network Stations
Institutional Total Diet Sampling Network Stations
PMN + ITDSN Stations
0 100 200 300 Miles
0 100 200 300 400 Kilometers

Figure 1. ITDSN and PMN sampling stations

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than 1 percent of the maximum permissible concentration for milk and food consumed by the general population.

Analytical procedures

The carbon-14 content is determined by combustion of the milk or food sample and collection and purification of the evolved carbon dioxide. The carbon dioxide is then converted to methane and counted in a gas-proportional counter (*1*).

Results and discussion

The carbon-14 concentration in food and milk was measured as dpm of carbon-14 per gram of carbon and converted to pCi/kg by using the percent carbon in the sample. The carbon content in food ranged from 9.9 to 11.0 percent with an average of 10.3 percent, and the carbon content in milk ranged from 4.9 to 6.5 percent with an average of 5.5 percent.

Table 1 shows the carbon-14 concentrations in total diet and milk for July–December 1970. The total diet average of 820 pCi/kg is lower than the average of 890 pCi/kg for the first half of 1970. The milk average of 430 pCi/kg is also lower than the average of 470 pCi/kg for the first half of 1970. The data show a gradual downward trend since 1965.

Table 1. Carbon-14 in total diet and milk July–December 1970

Location		Date collected (1970)	Concentration (pCi/kg ±2σ)	
			Total diet	Milk
Alaska:	Palmer	October	790±13	400± 9
Calif:	Los Angeles	November	830±13	
		October		420± 8
Hawaii:	Honolulu	NS	NS	NS
Idaho:	Idaho Falls	October	860±13	410±10
Ill:	Chicago	October	NS	450± 8
La:	New Orleans	October	820±13	440±10
Mass:	Boston	October	780±15	430± 8
Oreg:	Portland	October	840±13	420± 9
S.C:	Charleston	October	790±13	470± 8
Average			820	430

NS, no sample.

REFERENCE

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Other coverage in *Radiological Health Data and Reports:*

Period	Issue
July 1965—December 1968	November 1969
January 1969—June 1970	January 1971

Radionuclides in Institutional Diet Samples, October-December 1970 and Annual Summary 1970

Environmental Protection Agency and *Food and Drug Administration*

The determination of radionuclide concentrations in the diet constitutes an important element of an integrated program of environmental radiological surveillance and assessment. In recognition of the potential significance of the diet in contributing to total environmental radiation exposures, the Public Health Service (PHS) initiated its Institutional Diet Sampling Program in 1961. The program is administered by the Office of Radiation Programs, EPA, with the assistance of the Bureau of Food Sanitation, Food and Drug Administration (*1*).

The program was designed to provide estimates of the dietary intake of radionuclides in a selected population group ranging from children to young adults of school age. At the present time 25 institutions, distributed geographically as shown in figure 1, are being sampled. The station at Columbia, Miss., was discontinued because of cessation of the Atomic Energy Commission's testing activities at Hattiesburg, Miss. Previous results showed that the daily dietary intake of teenage girls and children from 9 to 12 years of age were comparable, while teenage boys con-

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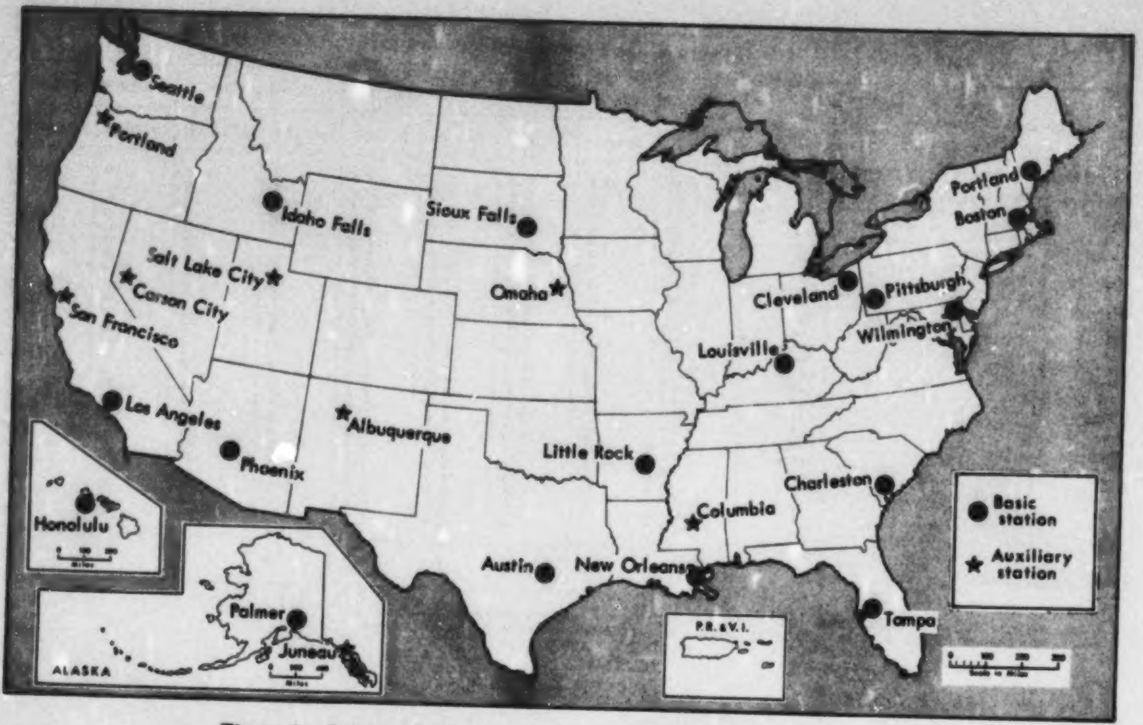
Seattle
Portland
Idaho Falls
Sioux Falls
Salt Lake City
Carson City
Omaha
San Francisco
Portland
Boston
Cleveland
Pittsburgh
Wilmington
Louisville
Los Angeles
Albuquerque
Phoenix
Little Rock
Charleston
Columbia
Honolulu
Austin
New Orleans
Tampa
Palmer
Juneau
ALASKA
P.R. & V.I.
Basic station
Auxiliary station
Miles

Figure 1. Institutional diet sampling locations as of December 1970

sumed 20 percent more food per day (*1*, *2*). Consequently, estimates for teenage boys and/or girls can be calculated on the basis of the dietary intake of children.

In general, the sampling procedure is the same at each institution. Each sample represents the edible portion of the diet for a full 7-day week (21 meals plus soft drinks, candy bars, or other in-between snacks) obtained by duplicating the meals of a different individual each day. Drinking water, not included in the samples, is also sampled periodically. Each daily sample is kept frozen until the end of the collection period and is then packed in dry ice and shipped by air express to either the Western Environmental Radiation Laboratory, Las Vegas, Nev; the Eastern Environmental Radiation Laboratory, Montgomery, Ala; or the PHS Northeastern Radiological Health Laboratory, Winchester, Mass. A detailed description of sampling and analytical procedures was presented earlier (*3*).

Results

Table 1 presents the analytical results for institutional diet samples collected from all stations during October through December 1970. The data for the basic and auxiliary stations have been combined into one table since the levels of radioactivity and intake are similar. The stable elements, calcium and potassium, are reported in g/kg of diet. The radionuclide concentrations of these samples, reported in pCi/kg of diet, are corrected for radioactive decay to the midpoint of the sample collection period, where applicable. Dietary intakes in g/day or pCi/day were obtained by multiplying the food consumption rate in kg/day by the appropriate concentration values. The average food consumption rate during this period was 1.82 kg/day compared to the network average of 1.87 kg/day observed from 1961 through 1969.

Table 1. Concentration and intake of stable elements and radionuclides in institutional total diets of children (9–12 years of age), October–December 1970

Location of institution		Month (1970)	Total weight (kg/day)	Calcium		Potassium		Strontium-90		Cesium-137	
				(g/kg)	(g/day)	(g/kg)	(g/day)	(pCi/kg)	(pCi/day)	(pCi/kg)	(pCi/day)
Alaska:	Juneau	Oct.	1.87	0.6	0.9	1.8	2.8	4	6	19	30
	Palmer	Oct.	1.30	.9	1.1	1.8	2.5	7	9	11	14
Ariz:	Phoenix	Oct.	1.75	.5	.9	1.3	2.4	3	6	0	0
Ark:	Little Rock	Oct.	1.18	.8	.9	1.6	1.9	12	14	0	0
Calif:	Los Angeles	Nov.[a]	1.37	.5	.7	1.3	1.8	3	5	0	0
	San Francisco	Oct.	2.24	.4	1.0	1.5	3.4	3	7	0	0
Del:	Wilmington	Oct.	2.23	.6	1.4	1.5	3.4	5	11	0	0
Fla:	Tampa	Oct.[a]	1.71	.6	1.0	1.3	2.3	4	6	34	58
Hawaii:	Honolulu	Oct.[a]	2.46	.5	1.2	1.4	3.5	3	8	0	0
Idaho:	Idaho Falls	Oct.[a]	2.11	1.1	2.4	1.5	3.1	7	14	0	0
Ky:	Louisville	Oct.	2.33	.6	1.5	1.7	3.9	6	15	0	0
La:	New Orleans	Oct.[a]	1.93	.7	1.4	1.5	3.0	8	16	0	0
Maine:	Portland	Oct.	1.92	.9	1.8	1.7	3.3	10	18	6	0
Mass:	Boston	Oct	2.13	.6	1.4	1.2	2.5	6	14	0	0
Nebr:	Omaha	Oct.[a]	1.47	.7	1.0	1.5	2.2	5	7	0	0
Nev:	Carson City	Oct.	1.54	.5	.7	1.4	2.1	3	4	0	0
N. Mex:	Albuquerque	Oct.	2.58	.7	1.7	1.2	3.1	3	8	0	0
Ohio:	Cleveland	Oct.	.85	.6	.5	1.7	1.4	6	5	12	10
Oreg:	Portland	Oct.[a]	1.80	0.7	1.3	1.7	3.2	6	10	0	0
Pa:	Pittsburgh	Oct.[a]	2.22	.5	1.1	1.3	3.0	6	12	13	20
S.C:	Charleston	Oct.	1.70	.6	1.0	1.4	2.4	6	11	13	22
S. Dak:	Sioux Falls	Oct.[a]	.63	.5	.3	1.7	1.0	6	4	17	11
Tex:	Austin	Oct.[a]	2.07	.8	1.7	1.5	3.1	3	5	0	0
Utah:	Salt Lake City	Oct.[a]	2.32	.5	1.1	1.0	2.4	3	8	0	0
Wash:	Seattle	Oct.[a]	2.06	.5	1.1	1.3	2.8	6	13	0	0
Institutional average			1.82	0.6	1.2	1.5	2.7	5	9	5	7

[a] Food samples were collected fom two or more children who were not between tho ages of 9 and 12.
Note: Strontium-89, iodine-131, and barium-140 were not detectable at any station during this period.

Table 2. 1970 annual average concentration and intake of stable elements and radionuclides in institutional total diets of children (9–12 years of age)[a]

Location of institution		Total weight (kg/day)	Calcium[b]		Potassium		Strontium-90[b]		Cesium-137	
			g/kg	g/day	g/kg	g/day	pCi/kg	pCi/day	pCi/kg	pCi/day
Alaska:	Juneau[c]	1.42	0.4	0.6	1.6	2.3	3	4	13	19
	Palmer	1.22	.6	.7	1.5	1.7	6	7	13	15
Ariz:	Phoenix	1.59	.6	.9	1.4	2.2	5	9	0	0
Ark:	Little Rock[c]	1.20	.7	.8	1.6	1.9	10	12	9	11
Calif:	Los Angeles	1.35	.5	.6	1.1	1.5	3	4	0	0
	San Francisco[c]	1.98	.5	1.0	1.5	3.0	3	5	0	0
Del:	Wilmington	2.11	.7	1.6	1.5	3.2	5	10	1	2
Fla:	Tampa[c]	1.43	.5	.8	1.4	2.0	6	9	28	39
Hawaii:	Honolulu[c]	2.28	.4	1.0	1.4	2.3	1	3	3	8
Idaho:	Idaho Falls[c]	1.90	1.3	2.6	1.5	3.1	7	15	9	17
Ky:	Louisville	2.44	.6	1.5	1.7	4.0	7	17	6	16
La:	New Orleans[c]	1.61	.5	.9	1.4	2.3	7	12	2	3
Maine:	Portland	1.70	1.0	1.7	1.6	2.8	11	17	11	18
Mass:	Boston	2.13	.7	1.6	1.4	3.0	6	13	8	17
Miss:	Columbia[c,d]	2.09	1.1	2.3	1.5	2.9	9	18	16	35
Nebr:	Omaha[c]	1.80	1.0	1.7	1.6	2.9	5	9	1	2
Nev:	Carson City	1.58	.7	1.2	1.5	2.3	7	12	6	8
N. Mex:	Albuquerque	2.28	.8	1.8	1.4	3.1	3	7	2	5
Ohio:	Cleveland[c]	1.33	.8	1.1	1.6	2.1	8	11	3	10
Oreg:	Portland[c]	1.85	.6	1.1	1.8	3.3	3	5	3	7
Pa:	Pittsburgh[c]	2.25	.5	1.2	1.4	3.1	6	13	10	24
S.C:	Charleston[c]	1.84	.6	1.2	1.3	2.5	8	15	9	18
S. Dak:	Sioux Falls[c]	1.16	.7	.8	1.7	1.9	6	7	7	6
Tex:	Austin[c]	1.83	.8	1.4	1.5	2.8	4	6	1	2
Utah:	Salt Lake City[c]	2.31	.5	1.1	1.2	2.8	2	6	0	0
Wash:	Seattle[c]	2.14	.5	1.1	1.4	3.0	5	10	0	0
Network average		1.80	.7	1.2	1.5	2.6	6	10	6	11

[a] Strontium-89, iodine-131, and barium-140 were not detected at most stations during 1970. The one exception is as follows: February—11 pCi/kg of iodine-131 was reported in Cleveland, Ohio.
[b] Composite of monthly samples during first 6 months of year.
[c] Food samples were collected from two or more children who were not between the ages of 9 and 12.
[d] Nine-month sample.

Strontium-90 dietary intake averaged 9 pCi/day and cesium-137 intake averaged 7 pCi/day during this period. These results fall within Range I as defined by the Federal Radiation Council (4). Strontium-89, barium-140, and iodine-131 concentrations were below detectable levels.

All concentrations that are less than or equal to the appropriate minimum detectable level have been reported as zero. The minimum detectable concentration is defined as the measured concentration equal to the 2-standard deviation analytical error. Accordingly, the minimum detectable limits are as follows:

Strontium-89	5 pCi/kg
Strontium-90	2 pCi/kg
Iodine-131	10 pCi/kg
Barium-140	10 pCi/kg
Cesium-137	10 pCi/kg

Annual average radionuclide concentrations and intakes are presented in table 2 for all stations. During 1970, the annual average intake for these institutions was 1.80 kg/day as compared to the network average of 1.87 kg/day observed from 1961 through 1969. The average levels of radionuclide concentrations are similar to previous years except that average concentrations of cesium-137 have been decreasing during the last few years.

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Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January—March 1970	November 1970
April—June 1970	January 1971
July—September 1970	February 1971

SECTION II. WATER

The Environmental Protection Agency and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (2–4), set the limits for approval of a drinking water supply containing radium-226 and strontium-90 at 3 pCi/liter and 10 pCi/liter, respectively. Higher concentrations may be acceptable if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities reported in *Radiological Health Data and Reports* are listed below.

Water sampling program	Period reported	Issue
California	July–December 1968	August 1970
Interstate Carrier Drinking Water	1967–1969	December 1970
Kansas	January–December 1969	September 1970
Minnesota	July–December 1969	May 1971
North Carolina	January–December 1967	May 1969
New York	January–June 1969	June 1970
Radiostrontium in Tap Water, *HASL*	January–December 1969	July 1970
Tritium in Community Water Supplies	1969	December 1970
Tritium Surveillance System	December 1970	May 1971
Washington	July 1968–June 1969	February 1971

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[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

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(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Radioactivity in Minnesota Municipal Water Supplies, July-December 1969

Division of Environmental Sanitation
Minnesota Department of Health

The analysis of various Minnesota waters for radioactivity was initiated in 1956 as part of the Minnesota Water Pollution Control Program. This program was expanded in 1958 to include most of the municipal surface water supplies in the State, as well as selected lakes throughout the State.

As many as 25 surface streams and lakes involving 74 stations have been sampled. At present, nine surface streams and lakes used as municipal water supplies are sampled routinely (figure 1). "Grab" samples of raw and treated water are collected weekly at Hallock, East Grand Forks, Eveleth, Fairmont, and St. Paul. Beginning in November 1969, weekly samples from these stations were composited and analyzed on a monthly basis. Monthly samples are taken at Crookston, International Falls, and St. Cloud. Minneapolis tap water is analyzed weekly. No raw water is collected from the Minneapolis supply.

The samples are forwarded to the Division's laboratory, where they are analyzed for gross alpha and beta radioactivity. A 500-ml sample of water is evaporated in a 2-inch aluminum milk-bottle-lid planchet and counted in an internal-proportional gas-flow counter. Counter standardization is accomplished by adding known amounts of thallium-204 standard to solutions containing the normal range of solids.

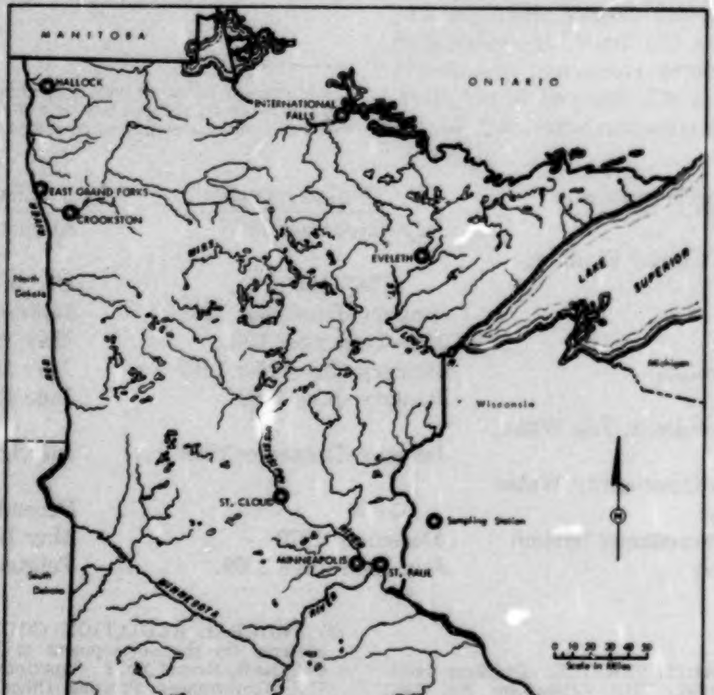
MANITOBA
ONTARIO
HALLOCK
INTERNATIONAL FALLS
EAST GRAND FORKS
CROOKSTON
RED RIVER
North Dakota
MISS.
EVELETH
LAKE SUPERIOR
Michigan
Wisconsin
ST. CLOUD
MISSISSIPPI
RIVER
Sampling Station
MINNEAPOLIS
ST. PAUL
South Dakota
MINNESOTA
RIVER
0 10 20 30 40 50
Scale in Miles
FAIRMONT
Iowa

Figure 1. Minnesota surface water sampling locations

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[1] Data and information from "Survey of Environmental Radioactivity, July–December 1969." State of Minnesota Department of Public Health, University Campus, Minneapolis, Minn. 55440, Publication No. C09–651–82.

Table 1. Average gross beta radioactivity in Minnesota raw and treated water supplies, July–December 1969

Town and water source	Type of water	Average concentrations (pCi/liter)					
		July	Aug	Sept	Oct	Nov	Dec
Crookston, Red Lake River	Raw	NS	18	18	5	18	21
	Treated	NS	17	19	17	17	18
East Grand Forks, Red Lake River	Raw	[a]17 (4)	17 (4)	10 (4)	14 (4)	[b]20	[b]17
	Treated	8 (4)	9 (4)	9 (4)	8 (4)	[b]9	[b]8
Eveleth, St. Mary's Lake	Raw	11 (5)	13 (4)	13 (3)	10 (5)	[b]13	[b]12
	Treated	12 (5)	13 (4)	12 (3)	11 (5)	[b]11	[b]14
Fairmont, Budd Lake	Raw	12 (5)	10 (4)	9 (3)	9 (5)	[b]10	[b]12
	Treated	5 (5)	5 (4)	7 (3)	4 (5)	[b]4	[b]8
Hallock, Two Rivers-South Fork	Raw	20 (4)	21 (4)	10 (3)	19 (5)	[b]17	[b]24
	Treated	7 (4)	7 (4)	8 (3)	10 (5)	[b]10	[b]10
International Falls, Rainy River	Raw	8	10	9	10	10	6
	Treated	6	9	7	7	8	6
Minneapolis tap water	Treated	7 (4)	4 (4)	4 (4)	4 (4)	[b]4	[b]4
St. Cloud, Mississippi River	Raw	10	4	6	7	8	NA
	Treated	4	10	4	2	8	NA
St. Paul, Vadnais Chain of Lakes	Raw	10 (5)	10 (4)	11 (3)	9 (5)	[b]12	[b]10
	Treated	6 (5)	6 (4)	4 (3)	6 (5)	[b]6	[b]4

[a] Number in parenthesis gives number of samples averaged.
[b] Composite sample.
NA, no analysis.
NS, no sample.

Table 2. Average gross alpha radioactivity in Minnesota raw and treated water supplies, July–December 1969

Town and water source	Type of water	Average concentrations (pCi/liter)					
		July	Aug	Sept	Oct	Nov	Dec
Crookston, Red Lake River	Raw	NS	0	0	0	0	5
	Treated	NS	0	0	0	0	0
East Grand Forks, Red Lake River	Raw	[a]1 (4)	1 (4)	0 (4)	0 (4)	[b]0	[b]0
	Treated	0 (4)	0 (4)	0 (4)	0 (4)	[b]0	[b]0
Eveleth, St. Mary's Lake	Raw	0 (5)	0 (4)	0 (3)	0 (5)	[b]0	[b]0
	Treated	0 (5)	0 (4)	0 (3)	0 (5)	[b]0	[b]0
Fairmont, Budd Lake	Raw	3 (5)	5 (4)	1 (3)	4 (5)	[b]0	[b]0
	Treated	0 (5)	0 (4)	0 (3)	0 (5)	[b]0	[b]0
Hallock, Two Rivers South Fork	Raw	0 (4)	1 (4)	0 (3)	0 (5)	[b]0	[b]0
	Treated	0 (4)	0 (4)	0 (3)	0 (5)	[b]0	[b]0
International Falls, Rainy River	Raw	0	0	0	0	0	0
	Treated	0	0	0	0	0	0
Minneapolis tap water	Treated	0 (4)	0 (4)	0 (4)	0 (4)	[b]0	[b]0
St. Cloud, Mississippi River	Raw	0	0	1	0	0	NA
	Treated	0	0	0	0	0	NA
St. Paul, Vadnais Chain of Lakes	Raw	0 (5)	0 (4)	1 (3)	0 (5)	[b]0	[b]0
	Treated	0 (5)	<1 (4)	0 (3)	<1 (5)	[b]0	[b]0

[a] Number in parenthesis gives number of samples averaged.
[b] Composite sample.
NA, no analysis.
NS, no sample.

Table 1 shows a summary of the monthly average gross beta radioactivity in Minnesota municipal water supplies from July–December 1969. Table 2 shows the gross alpha radioactivity in the same samples for the same period of time. Alpha concentrations reported as <1 pCi/liter were considered as 0 pCi/liter for averaging purposes.

The data obtained on gross beta radioactivity in Minnesota surface waters show a variation of concentrations, with no readily apparent trends. Variations in precipitation and flow rates of streams could contribute to this fluctuation. Monthly averages of gross beta radioactivity in Minnesota raw surface waters ranged from 2 to 24 pCi/liter, which is well below the Public Health Service Drinking Water Standards (*1*).

REFERENCE

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–June 1969	January 1970

Tritium Surveillance System, July-December 1970

Office of Radiation Programs
Environmental Protection Agency

This is the first in a series of data articles on the Tritium Surveillance System which began in July 1970 and is an expansion of previous tritium surveillance activities conducted by the Office of Radiation Programs, Environmental Protection Agency (EPA). The principal effort in the past by the Office of Radiation Programs related to tritium releases has been the Tritium in Surface Water Network. This network was established in 1964 to measure and monitor tritium concentrations in major river systems in the United States and to provide surveillance at surface water stations downstream from selected nuclear facilities. The network consisted of selected stations from existing water pollution sampling stations operated by the Water Quality Office of EPA. The final data from this network for January–June 1970 have been published previously (*1*).

Another effort of the Radiation Office was a tritium-in-precipitation program. This project was established in 1967 at selected Radiation Alert Network (RAN) stations covering the United States, including Alaska and Hawaii. The RAN is operated by the Office of Air Programs of EPA. The data from this project for July–December 1969 have been published previously (*2*). Due to the increased interest in tritium releases from nuclear facilities and the potential long-term accumulation in the environment, a national

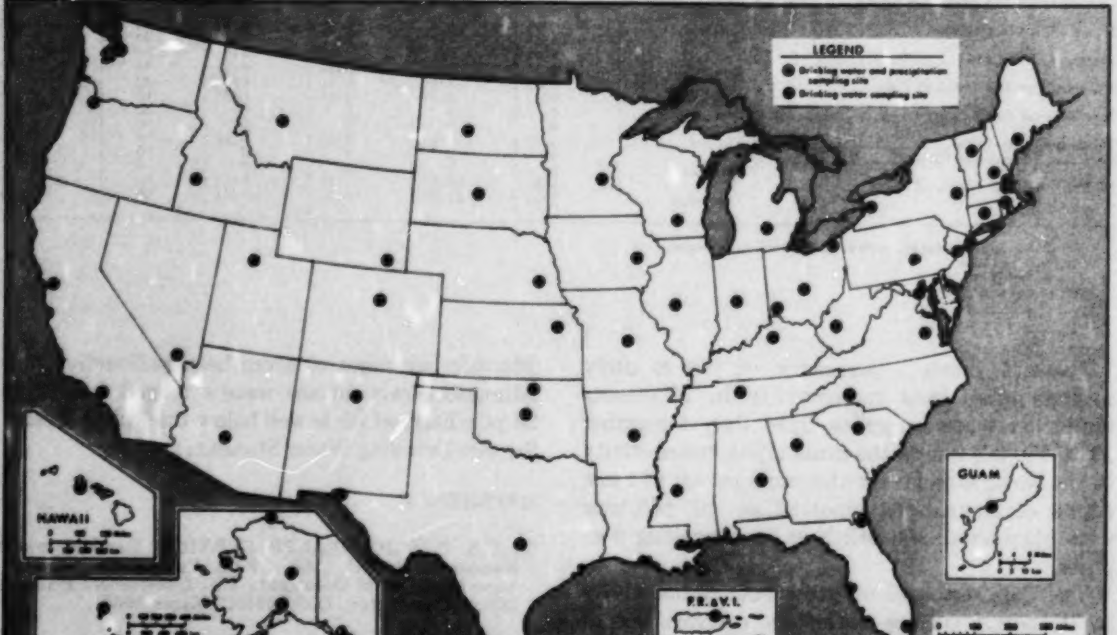
LEGEND
● Drinking water and precipitation sampling site
● Drinking water sampling site
HAWAII
ALASKA
GUAM
P.R.&V.I.

Figure 1. Drinking water and precipitation sampling locations for tritium surveillance system

system has been established to incorporate these projects or networks into one overall system.

Present network

The Tritium Surveillance System consists of 70 quarterly drinking water samples at the RAN stations, precipitation samples collected daily and analyzed monthly from 8 of the RAN stations (figure 1), and quarterly samples at 39 surface water stations (figure 2). The specific locations for the surface water sampling system were determined by examining the water drainage areas to assure that a representative sample from a large area or region was obtained, and if possible, incorporating several nuclear facility sites. All nuclear facilities that were operating through 1970, being constructed, or planned through 1975 were considered. Consideration was also given to the current surveillance programs of the States that will be involved in the collection of the samples. The surface water samples are collected quarterly either downstream from a nuclear facility or at a background station.

The tap water samples are collected by the RAN operators on a quarterly basis. The precipitation samples are also collected by the RAN operators on a daily basis.

All samples are sent to one of our laboratories for analysis. Due to the different sensitivity of procedures used by the three laboratories, the minimum detectable concentration varies. Analytical values which are not statistically significant at the 2-sigma confidence level have been reported as zero.

Results and discussion

Table 1 presents the tritium concentrations in drinking water at the RAN stations for 1970. Although the quarterly tap water collections did not begin until July 1970, a one-time collection of tap water during the first 6 months of 1970 is also included in table 1. The average tritium concentration was 0.3 nCi/liter for the first 6 months and 0.2 nCi/liter for each of the last two quarters.

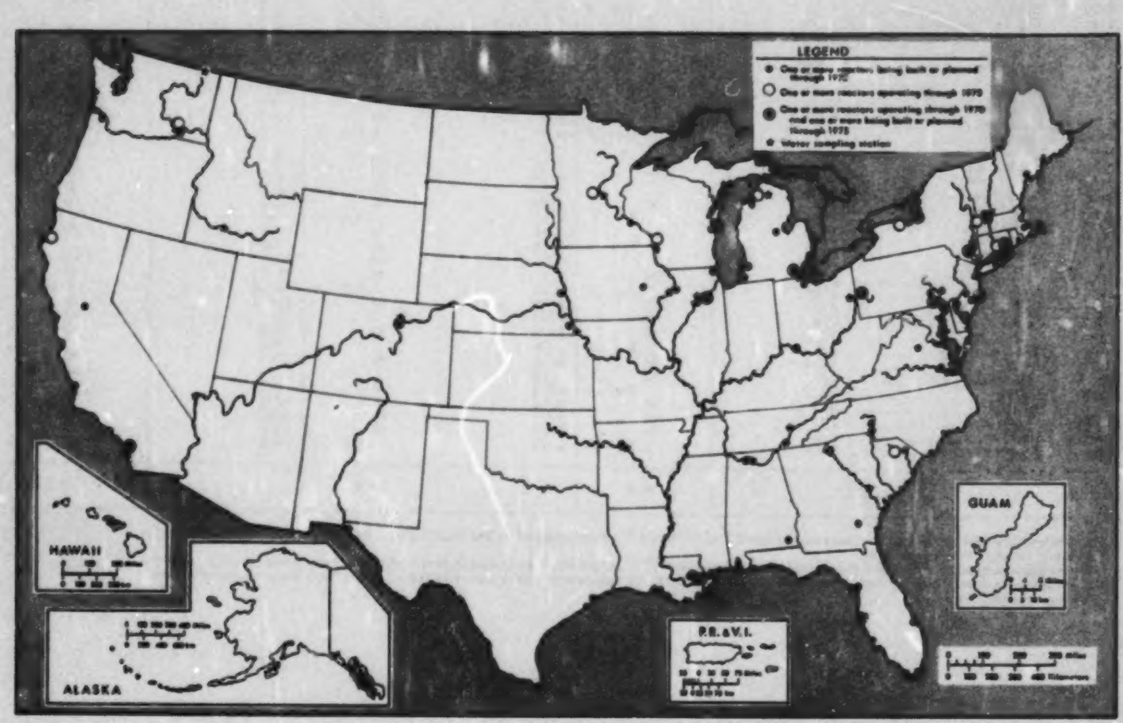
LEGEND
● One or more reactors being built or planned through 1975
○ One or more reactors operating through 1970
● One or more reactors operating through 1970 and one or more being built or planned through 1975
● Water sampling station
HAWAII
ALASKA
P.R. & V.I.
GUAM

Figure 2. Surface water sampling locations for tritium surveillance system

Table 1. Tritium concentration in tap water, (RAN stations) January–December 1970

Location		Date collected (January–June)	Tritium concentration (nCi/liter ±2σ)	Date collected (July–September)	Tritium concentration (nCi/liter ±2σ)	Date collected (October–December)	Tritium concentration (nCi/liter ±2σ)
Ala:	Montgomery	3/25	[a]0	8/17	[a]0	10/2	[a]0
Alaska:	Adak	2/3	0.6±0.4	9/8	0.6±0.4	10/1, 12/29	[b,c]0.3
	Anchorage	NS		8/18, 9/7	[b,c].5	10/4, 10/13	[b,c]0
	Attu Island	NS		8/14	[a]0	10/1	.5±.4
	Fairbanks	2/5	.4± .4	8/11	[a]0	NS	
	Juneau	NS		9/8	.7± .4	10/5	.5±.4
	Kodiak	1/26	[a]0	NS		10/2	.4±.4
	Nome	NS		NS		NS	
	Point Barrow	2/6	1.1± .4	9/30	1.3± .4	NS	
	St. Paul Island	2/19	.9± .4	NS		10/7	.5±.4
Ariz:	Phoenix	NS		8/1	[a]0	NS	
Ark:	Little Rock	2/17	[a]0	8/7	[a]0	10/6	[a]0
Calif:	Berkeley	NS		8/11	[a]0	10/1	.6±.4
	Los Angeles	1/21	[a]0	8/7	[a]0	10/2	.5±.4
C.Z:	Ancon	4/6	[a]0	9/1	[a]0	11/4	[a]0
Colo:	Denver	NS		8/11, 9/23	[b,c]1.1	10/4, 10/27	[b,c]1.1
Conn:	Hartford	1/28	[d]0	8/11	[a]0	10/1	[d]0
Del:	Dover	NS		8/31	[d]0	10/1	[d]0
D.C:	Washington	2/4	[a]0	8/11	[a]0	10/15	[a]0
Fla:	Jacksonville	NS		7/30, 8/7	[a,b]0	10/5	[a]0
	Miami	2/4	[a]0	8/7	[a]0	10/5	[a]0
Ga:	Atlanta	2/5	[a]0	8/10	[a]0	10/5	.3±.2
Guam:	Agana	NS		NS		NS	
Hawaii:	Honolulu	NS		8/17	[a]0	10/8	[a]0
Idaho:	Boise	1/21	.7± .4	8/12	.5± .4	10/2	.9±.4
Ill:	Springfield	1/26	[d]0	8/7	.7± .6	10/1	[d]0
Ind:	Indianapolis	1/22	[d]0	8/31	[d]0	10/1	[d]0
Iowa:	Iowa City	1/26	.6± .4	8/11	[a]0	10/12	[a]0
Kans:	Topeka	1/21	[a]0	8/10	[a]0	10/5	.5±.4
Ky:	Frankfort	2/5	.3± .2	8/17	[a]0	10/7	[a]0
La:	New Orleans	2/6	[a]0	7/30	[a]0	10/8	[a]0
Maine:	Augusta	1/23	[d]0	8/11	[d]0	10/1	[d]0
Md:	Baltimore	2/5	.5± .2	8/12	[a]0	10/8	[a]0
	Rockville	6/15	[a]0	NS		NS	
Mass:	Lawrence	NS		8/31	[d]0	10/1	[d]0
	Winchester	1/26	[d]0	8/11	[d]0	10/1	[d]0
Mich:	Lansing	1/26	[d]0	8/12	[d]0	10/2	[d]0
Minn:	Minneapolis	NS		8/14, 9/14	[b,c]1.0	10/14, 10/14	[b,c].6
Miss:	Jackson	2/6	[a]0	8/7	[a]0	10/6	[a]0
Mo:	Jefferson City	1/22	[d]0	8/10	[a]0	10/1	[a]0
Mont:	Helena	NS		8/10, 9/3	[b,c]1.2	10/2	1.1±.4
Nebr:	Lincoln	1/27	.6± .4	8/10	[a]0	10/5, 11/17	[b,c].4
Nev:	Las Vegas	1/20	[a]0	8/7, 9/18	[b,c].8	NS	
N.H:	Concord	3/9	[d]0	8/11	[d]0	10/1	[d]0
N.J:	Trenton	NS		8/12	[d]0	NS	
N. Mex:	Santa Fe	1/21	.9± .4	NS		10/1, 10/2, 12/31	[b,c].4
N.Y:	Albany	1/26	[d]0	8/11	[d]0	10/1	[d]0
	Buffalo	NS		8/12	[d]0	10/1	[d]0
	New York City	1/26	[d]0	NS		NS	
N.C:	Gastonia	2/6	[a]0	8/7	[a]0	10/6	[a]0
N.Dak:	Bismarck	1/27	2.0± .4	9/15	1.0± .4	10/7	1.3±.4
Ohio:	Cincinnati	1/27	[d]0	NS		10/1	[d]0
	Columbus	1/22	[d]0	8/12	[d]0	10/1	[d]0
	Painesville	NS		8/12	[d]0	10/1	[d]0
Okla:	Oklahoma City	NS		8/11	[a]0	10/9	[a]0
	Ponca City	2/5	[a]0	8/10	[a]0	10/8	[a]0
Oreg:	Portland	NS		9/3	.6± .4	NS	
Pa:	Harrisburg	1/26	[d]0	8/12	[d]0	10/1	[d]0
P.R:	San Juan	NS		9/14	[a]0	NS	
R.I:	Providence	NS		8/11	[d]0	10/1	[d]0
S.C:	Columbia	2/20	[a]0	8/6	[a]0	10/6	[a]0
S.Dak:	Pierre	2/6	2.3± .4	8/31	1.7± .4	10/12	1.6±.4
Tenn:	Nashville	2/4	[a]0	8/10	[a]0	10/12	[a]0
Tex:	Austin	2/20	[a]0	NS		10/7	[a]0
	El Paso	4/3	[a]0	8/10	[a]0	10/8	[a]0
Utah:	Salt Lake City	2/6	.6± .4	NS		NS	
Vt:	Barre	1/29	[d]0	8/11	[a]0	10/1	[d]0
Va:	Richmond	2/17	[a]0	NS		10/8	[a]0
Wash:	Seattle	2/16	.7± .4	8/13	[a]0	NS	
	Spokane	2/2	[a]0	8/11	[a]0	10/1	[a]0
W. Va:	Charleston	2/20	[a]0	8/7	[a]0	10/5	[a]0
Wisc:	Madison	1/26	[d]0	8/31	[d]0	10/1	[d]0
Wyo:	Cheyenne	3/23	1.3± .4	8/10	.8± .4	10/2	1.3±.4
Average			0.3		0.2		0.2

[a] The minimum detection limit for this sample was 0.2 nCi/liter. All values equal to or less than 0.2 nCi/liter have been reported as zero.
[b] Average of two or more samples.
[c] The minimum detection limit for this sample was 0.4 nCi/liter. All values equal to or less than 0.4 nCi/liter have been reported as zero.
[d] The minimum detection limit for this sample was 0.6 nCi/liter. All values equal to or less than 0.6 nCi/liter have been reported as zero.
NS, no sample.

Table 2. Tritium concentration in surface water, July–December 1970

Location	Water source	Facility	Collection date (July–Sept)	Concentration (nCi/liter ±2σ)	Collection date (Oct–Dec)	Concentration (nCi/liter ±2σ)
Ala:						
Decatur	Tennessee River	Browns Ferry	7/29	0.4±0.2	10/17	[a]0
Ark:						
Russellville	Lake Dardanelle (Arkansas River)	Arkansas Nuclear	7/16	[a]0	12/15	[a]0
Calif:						
Eureka	Humboldt Bay	Humboldt Bay	9/11	[b]0	10/5	[b]0
San Onofre	Pacific Ocean	San Onofre	9/22	[c]2.5± .4	12/2	[b]0
Colo:						
Greeley	South Platte River	Fort St. Vrain	8/11	1.1± .4	11/6	[d]1.0±.4
Conn:						
East Haddam	Connecticut River	Connecticut Yankee and Vermont Yankee	8/13	3.5± .6	10/14	[a]0
Waterford	Long Island Sound	Millstone	8/13	[a]0	10/14	[a]0
Fla:						
Crystal River	Gulf of Mexico	Crystal River	8/11	[a]0	10/15	[a]0
Key Largo	Biscayne Bay	Turkey Point	8/6	[a]0	11/4	[a]0
Idaho:						
Buhl	Snake River	National Reactor Testing Station	NS		10/27	.4±.4
Ill:						
Moline	Mississippi River	Quad-Cities	NS		10/29	[a]0
Morris	Illinois River	Dresden and Argonne	NS		10/9	[a]0
La:						
New Orleans	Mississippi River	(Several)	9/3	.3± .2	10/13	[a]0
Md:						
Conowingo	Susquehanna River	Peach Bottom and Three Mile Island	8/13	[a]0	10/7	[a]0
Lusby	Chesapeake Bay	Calvert Cliffs	9/29	[a]0	11/17	[a]0
Mass:						
Rowe	Deerfield River	Yankee	8/14	8.2± .6	10/6	[a]0
Mich:						
Charlevoix	Lake Michigan	Big Rock Point	9/6	[a]0	NS	
Monroe	Lake Erie	Enrico Fermi	9/12	[a]0	NS	
South Haven	Lake Michigan	Palisades	9/8	[a]0	NS	
Minn:						
Monticello	Mississippi River	Monticello	NS		NS	
Nebr:						
Rulo	Missouri River	Fort Calhoun and Cooper	NS		10/5	1.0±.4
Nev:						
Boulder City	Colorado River	Background	9/7	1.2± .4	10/7, 12/16	[b,f]1.6
N.J:						
Bayside	Delaware River	Salem	8/31	[a]0	11/10	[a]0
N.Y:						
Ossining	Hudson River	Indian Point	8/21	[a]0	10/6	[a]0
Oswego	Lake Ontario	Nine Mile Point and R. E. Ginna	8/10	[a]0	10/1	[a]0
Poughkeepsie	Hudson River	Background	9/16	[a]0	10/14	[a]0
N.C:						
Charlotte	Catawba River	Wm. B. McGuire	8/27	.3± .2	12/29	.3±.2
S.C:						
Allendale	Savannah River	Savannah River Plant and Oconee	8/3	4.9± .3	12/18	10.3±.3
Hartsville	Lake Robinson	H. B. Robinson	7/15	[a]0	10/9	[a]0
Tenn:						
Kingston	Clinch River	Oak Ridge	7/6, 9/7	[a,f]1.2	10/16	2.6±.2
Tex:						
El Paso	Rio Grande River	Los Alamos	9/1, 9/2	[b,e]0	10/6	.5±.4
Vt:						
Vernon	Connecticut River	Vermont Yankee	7/31	[a]0	10/5	[a]0
Va:						
Surry	James River	Surry	8/13	[a]0	11/19	[a]0
Wash:						
Northport	Columbia River	Background	9/20	.9± .4	10/5, 10/16	[b,f].5
Pasco	Columbia River	Hanford	8/26	1.3± .4	10/2	1.0±.4
W. Va:						
Wheeling	Ohio River	Shippingport	8/25	[a]0	10/16	[a]0
Wisc:						
La Crosse	Mississippi River	La Crosse and Prairie Island	8/28	[a]0	10/6	[a]0
Two Creeks	Lake Michigan	Point Beach and Kewaunee	8/31	[a]0	10/12	[a]0
Average				0.8		0.6

[a] The minimum detection limit for this sample was 0.2 nCi/liter. All values equal to or less than 0.2 nCi/liter have been reported as zero.
[b] The minimum detection limit for this sample was 0.4 nCi/liter. All values equal to or less than 0.4 nCi/liter have been reported as zero.
[c] This sample was collected in San Clemente.
[d] This sample was collected in Denver.
[e] The minimum detection limit for this sample was 0.6 nCi/liter. All values equal to or less than 0.6 nCi/liter have been reported as zero.
[f] Average of two samples.
NS, no sample.

The radiation dose resulting from the observed tritium concentrations in the drinking water may be evaluated by using the relationship derived by Moghissi and Porter (*3*) from recommendations of the International Commission of Radiological Units and Measurements (*4*). Assuming that the concentration of tritium in all water taken into the body is equal to that found in the drinking water and also that the specific activity of tritium in the body is essentially the same as that in the drinking water, then the radiation dose may be estimated.

The highest individual concentration of tritium observed in the drinking water for the one time collection during the first 6 months of 1970 was 2.3 nCi/liter, 1.7 nCi/liter during the third quarter, and 1.6 nCi/liter during the fourth quarter. This corresponds to a dose of 0.4, 0.3, and 0.3 mrem/a, respectively, or less than 0.3 percent of the Federal Radiation Council's Radiation Protection Guide (170 mrem/a) for an average dose to a suitable sample of the exposed population.

The tritium concentrations for the surface water samples are given in table 2. The highest tritium concentration was 8.2 and 10.3 nCi/liter for the third and fourth quarters, respectively. Assuming that the specific activity of tritium in the body is essentially the same as that in surface water, these concentrations correspond to a dose of 1.4 and 1.8 mrem/a, respectively, or 0.8 and 1.0 percent of the Radiation Protection Guide.

The monthly analyses for tritium in precipitation samples at the 8 RAN stations are shown in table 3.

Miscellaneous tritium data

During the period from October 1969 through May 1970, the Division of Technology Assessment of the Office of Radiation Programs collected and analyzed surface water samples from 22 selected sites where nuclear power reactors were under construction or proposed and from one site where the reactor had recently started up. These samples were collected to determine the existing levels of tritium in surface water systems at or near power reactor sites. Lake or ocean samples were collected adjacent to the site or close to the planned discharge point, above the site, and below the site. For sites located on rivers, samples were collected adjacent to the site or near the planned discharge point and upstream from the site. A more comprehensive sampling was performed around the Calvert Cliffs facility. The data are presented in table 4 and the highest observed concentration was 1.2 nCi/liter.

REFERENCES

(*1*) BUREAU OF RADIOLOGICAL HEALTH. Tritium in surface water network, January–June 1970. Radiol Health Data Rep 11:638–639 (November 1970).

(*2*) BUREAU OF RADIOLOGICAL HEALTH. Tritium in precipitation, July–December 1969. Radiol Health Data Rep 11:364–365 (July 1970).

(*3*) MOGHISSI, A. A. and C. R. PORTER. Tritium in surface waters in the United States, 1966. Radiol Health Data Rep 9:337–339 (July 1968).

(*4*) INTERNATIONAL COMMISSION OF RADIOLOGICAL UNITS AND MEASUREMENTS. Recommendations of the International Commission of Radiological Units and Measurements, National Bureau of Standards Handbook 85 (1964).

Table 3. Tritium concentration in precipitation from RAN stations, January–December 1970

Location	Tritium concentration[a] (nCi/liter ±2σ)											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Alaska: Anchorage	0	0	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Ala: Montgomery	0	0	0	0	0.7±0.2	0	0.3±0.2	0	0	0	0	NS
Colo: Denver	NS	NS	0.4±0.2	0.6±0.2	1.1± .2	1.2±0.2	.6± .2	0.8±0.2	0	0.6±0.2	0.3±0.2	NS
Hawaii: Honolulu	0	NS	0	0	0	NS	0	0	0	0	0	0
La: New Orleans	NS	0	0	0	0	0	0	0	0	0	0	NS
N.C: Gastonia	0.3±0.2	0	.4± .2	0	0	.5± .2	0	0	0	0	0	0
Tex: Austin	0	NS	NS	0	0	NS	NS	NS	NS	NS	NS	NS
Wash: Seattle	0	0	0	.5± .2	0	0	.4± .2	0	0	0	0	0

[a] The minimum detection limit for these samples was 0.2 nCi/liter. All values equal to or less than 0.2 nCi/liter have been reported as zero.
NS, no sample.

Table 4. Tritium concentration in the vicinity of selected nuclear power reactor sites, October 1969–May 1970

Location	Water source	Facility	Date collected	Tritium concentration (nCi/liter ±2σ)
Ark: Russellville:	Lake Dardanelle (Arkansas River)	Arkansas Nuclear		
Upstream			1/27/70	[c]0
Downstream			1/27/70	[c]0
Fla: Ft. Pierce:	Atlantic Ocean	Hutchinson Island		
Atlantic Ocean			3/24/70	[c]0
Indian River			3/24/70	[c]0
Crystal River:	Gulf of Mexico	Crystal River		
Inlet			1/13/70	[c]0
Discharge			1/13/70	[c]0
Ga: Baxley:	Altamaha River	Edwin I. Hatch		
Upstream			2/5/70	0.4 ±0.2
Downstream			2/5/70	[c]0
Iowa: Cedar Rapids:	Cedar River	Duane Arnold		
Adjacent			10/16/69	1.1 ± .6
Upstream			10/16/69	[c]0
Md: Lusby:	Chesapeake Bay	Calvert Cliffs		
.23 miles E Cove Point			8/15/69	[c]0
.39 miles NE Rocky Point			8/15/69	[c]0
.67 miles NE site			8/15/69	[c]0
.28 miles NE site			8/15/69	[c]0
1.13 miles NE Calvert Beach			8/15/69	.7 ± .6
1.32 miles E Scientists Cliff			8/15/69	.6 ± .6
Mouth of Severn River			8/15/69	[c]0
Mouth of Severn River			11/12/69	[f][c]0
Middle Bay Bridge			8/15/69	[c]0
Middle Bay Bridge			11/12/69	[a].34 ± .08
Middle Bay Bridge			11/12/69	[a].10 ± .07
Mass: Plymouth:	Atlantic Ocean	Pilgrim		
Adjacent			5/6/70	[c]0
North			5/6/70	[c]0
South			5/6/70	[c]0
Mich: Bridgman:	Lake Michigan	Donald C. Cook		
Adjacent			10/13/69	[c]0
North			10/13/69	.8 ± .7
South			10/13/69	[c]0
Lagoona Beach:	Lake Erie	Enrico Fermi		
Adjacent			10/22/69	[c]0
North			10/22/69	1.0 ± .7
South			10/22/69	[c]0
Minn: Red Wing:	Mississippi River	Prairie Island		
Adjacent			10/15/69	[c]0
Upstream			10/15/69	1.0 ± .7
N.H: Seabrook:	Atlantic Ocean	Seabrook		
Adjacent			10/23/69	[c]0
North			10/23/69	[c]0
South			10/23/69	[c]0
Inlet			10/23/69	[c]0
N.J: Salem:	Delaware River	Salem		
Adjacent			5/1/70	[c]0
Upstream			5/1/70	[c]0
N.Y: Brookhaven:	Long Island Sound	Shoreham		
Adjacent			4/30/70	[c]0
East			4/30/70	[c]0
West			4/30/70	[c]0
Lansing:	Lake Cayuga	Bell		
Adjacent			4/28/70	[c]0
North			4/28/70	[c]0
South			4/28/70	[c]0
Rochester:	Lake Ontario	R. E. Ginna		
Adjacent			4/27/70	[c]0
East			4/27/70	[c]0
West			4/27/70	[c]0
N.C: Southport:	Cape Fear River	Brunswick		
Adjacent			[b]10/12/69	[c]0
Pa: Shippingport:	Ohio River	Beaver Valley		
Adjacent			10/17/69	[c]0
Upstream			10/17/69	[c]0
S.C: Hartsville:	Black Creek	H. B. Robinson		
Upstream			1/21/70	.4 ± .2
Downstream			1/21/70	[c]0
Seneca:	Keowee River	Oconee		
Upstream			1/16/70	[c]0
Downstream			1/16/70	[c]0
Tenn: Daisy:	Tennessee River	Sequoyah		
Upstream			3/10/70	.5 ± .2
Adjacent			3/10/70	.6 ± .2
Downstream			3/10/70	.4 ± .2
Va: Gravel Neck:	James River	Surry		
Upstream			1/27/70	[c]0
Downstream			1/27/70	[c]0
Mineral:	North Anna River	North Anna		
Upstream			1/27/70	[c]0
Downstream			1/27/70	[c]0

See footnotes at end of table.

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Table 4. Tritium concentration in the vicinity of selected nuclear power reactor sites October 1969–May 1970—Continued

Location	Water source	Facility	Date collected	Tritium concentrations (nCi/liter±2σ)
Wisc: Carlton:	Lake Michigan	Kewaunee		
Adjacent			10/14/69	1.1 ± .9
North			10/14/69	1.3 ± .8
South			10/14/69	.8 ± .7

[a] The minimum detection limit for this sample was 0.2 nCi/liter. All values equal to or less than 0.2 nCi/liter have been reported as zero.
[b] The minimum detection limit for this sample was 0.7 nCi/liter. All values equal to or less than 0.7 nCi/liter have been reported as zero.
[c] The minimum detection limit for this sample was 0.9 nCi/liter. All values equal to or less than 0.9 nCi/liter have been reported as zero.
[d] The minimum detection limit for this sample was 0.8 nCi/liter. All values equal to or less than 0.8 nCi/liter have been reported as zero.
[e] The minimum detection limit for this sample was 0.6 nCi/liter. All values equal to or less than 0.6 nCi/liter have been reported as zero.
[f] The minimum detection limit for this sample was 0.06 nCi/liter. All values equal to or less than 0.06 nCi/liter have been reported as zero.
[g] Sample was electrolytically enriched.
[h] Composite of three monthly samples.

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SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the Environmental Protection Agency, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports*:

Network	Period	Issue
Fallout in the United States and Other Areas, *HASL*	July–December 1968 and January–December 1969	January 1971
Plutonium in Airborne Particulates and Precipitation	January–June 1970	March 1971
Surface Air Sampling Program, 80th Meridian Network, *HASL*	January–December 1968	April 1971

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1. Radiation Alert Network
January 1971

Office of Air Programs
Environmental Protection Agency

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 70 locations distributed throughout the country (figure 1). Most of the stations are operated by State Health Department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate Environmental Protection Agency officials by mail or telephone depending on levels found. A compilation of the daily field estimates is available upon request from the Data Acquisition and Analysis Branch, Division of Air Quality and Emission Data, EPA, Cincinnati, Ohio. A detailed description of the sampling and analytical procedures was presented in the March 1968 issue of *Radiological Health Data and Reports.*

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique during January 1971.

All field estimates reported were within normal limits for the reporting station.

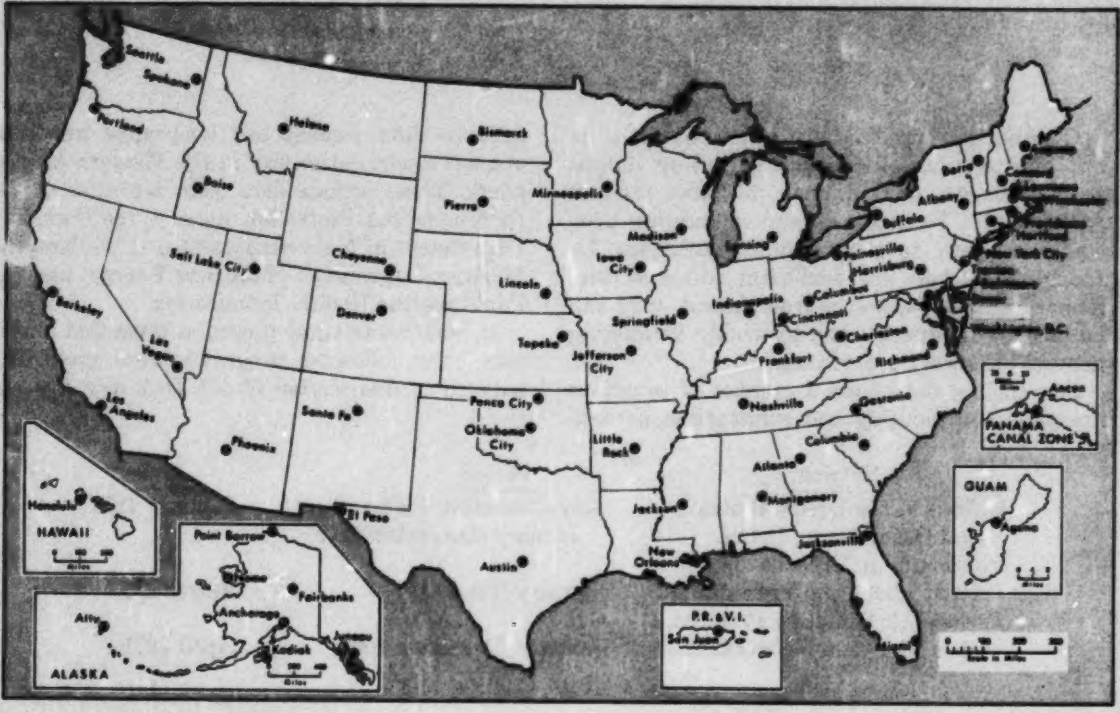
Seattle
Spokane
Portland
Helena
Bismarck
Boise
Pierre
Minneapolis
Salt Lake City
Cheyenne
Lincoln
Berkeley
Denver
Las Vegas
Topeka
Jefferson City
Los Angeles
Santa Fe
Ponca City
Oklahoma City
Phoenix
El Paso
Austin
Honolulu
HAWAII
Point Barrow
Fairbanks
Anchorage
Attu
Kodiak
Juneau
ALASKA
Madison
Iowa City
Lansing
Springfield
Indianapolis
Columbus
Cincinnati
Charleston
Frankfort
Richmond
Little Rock
Nashville
Gastonia
Columbia
Atlanta
Montgomery
Jackson
New Orleans
Jacksonville
Miami
Barre
Augusta
Concord
Albany
Buffalo
Painesville
Harrisburg
Hartford
New York City
Trenton
Washington, D.C.
Ancon
PANAMA CANAL ZONE
GUAM
Agana
P.R. & V.I.
San Juan
Scale in Miles

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, January 1971

Station location	Number of samples	Gross beta radioactivity (5-hour field estimate) (pCi/m³)			Precipitation				
		Maximum	Minimum	Average[a]	Number of samples	Total depth (mm)	Field estimation of deposition		
							Number of samples	Depth (mm)	Total deposition (nCi/m²)
Ala: Montgomery	17	5	0	1	4	53	4	53	10
Alaska: Anchorage	1	0	0	0	0				
Attu Island	25	0	0	0	0				
Fairbanks	0				0				
Juneau	5	12	0	4	3	96	3	96	0
Kodiak	2	0	0	0	0				
Nome	0				0				
Point Barrow	0				0				
Ariz: Phoenix	12	9	0	6	0				
Ark: Little Rock	17	2	0	0	0				
Calif: Berkeley	19	2	0	0	5	37	5	37	0
Los Angeles	20	2	0	1	0				
C.Z: Ancon	0				0				
Colo: Denver	18	8	0	1	1	2	(b)		
Conn: Hartford	19	0	0	0	6	40	6	40	5
Del: Dover	19	0	0	0	0				
D.C: Washington	23	0	0	0	0				
Fla: Jacksonville	20	2	0	0	4	56	4	56	8
Miami	13	0	0	0	1	13	1	13	0
Ga: Atlanta	18	2	1	1	1	60	1	60	22
Guam: Agana	0				0				
Hawaii: Honolulu	25	1	0	0	7	97	(b)		
Idaho: Boise	20	2	0	0	9	58	9	58	1
Ill: Springfield	1	1	1	1	0				
Ind: Indianapolis	19	2	0	0	0				
Iowa: Iowa City	19	1	0	0	1	54	1	54	17
Kans: Topeka	20	1	0	0	1	20	1	20	0
Ky: Frankfort	15	0	0	0	0				
La: New Orleans	19	1	0	0	4	47	(b)		
Maine: Augusta	19	1	0	0	4	31	4	31	0
Md: Baltimore	19	1	0	0	4	33	4	33	0
Mass: Lawrence	20	0	0	0	3	26	3	26	0
Winchester	20	0	0	0	4	33	4	33	0
Mich: Lansing	19	0	0	0	0				
Minn: Minneapolis	20	1	0	0	7	13	7	13	1
Miss: Jackson	14	0	0	0	3	107	3	107	9
Mo: Jefferson City	20	2	0	1	1	33	1	32	0
Mont: Helena	13	1	0	0	1	11	1	11	0
Nebr: Lincoln	18	4	0	2	1	22	1	22	12
Nev: Las Vegas	18	4	0	2	0				
N.H: Concord	0				0				
N.J: Trenton	18	0	0	0	6	56	6	56	1
N. Mex: Santa Fe	16	2	0	1	1	8	1	8	0
N.Y: Albany	1	0	0	0	0				
Buffalo	18	0	0	0	0				
New York City	0				0				
N.C: Gastonia	18	5	0	1	4	75	1	59	0
N. Dak: Bismarck	20	1	0	0	5	21	5	21	1
Ohio: Cincinnati	0				0				
Columbus	0				0				
Painesville	19	2	0	1	3	10	3	10	3
Okla: Oklahoma City	8	1	1	1	0				
Ponca City	20	4	0	1	1	38	1	38	0
Oreg: Portland	20	1	0	0	11	196	10	173	5
Pa: Harrisburg	13	0	0	0	0				
P.R: San Juan	0				0				
R.I: Providence	17	1	0	0	0				
S.C: Columbia	18	2	0	1	4	84	4	84	0
S. Dak: Pierre	20	2	0	1	0				
Tenn: Nashville	20	1	0	0	5	63	5	63	5
Tex: Austin	1	2	2	2	0				
El Paso	0				0				
Utah: Salt Lake City	27	2	0	1	4	11	4	11	0
Vt: Barre	20	1	0	0	7	21	7	21	3
Va: Richmond	19	1	0	0	6	55	6	55	11
Wash: Seattle	8	0	0	0	7	60	(b)		
Spokane	18	1	0	0	0				
W. Va: Charleston	18	1	0	0	5	38	4	37	5
Wisc: Madison	18	0	0	0	6	69	5	68	5
Wyo: Cheyenne	20	5	0	1	1	10	1	10	3
Network summary	970	12	0	1	151	52	4	44	4

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.
[b] This station is part of the plutonium in precipitation network. No gross beta measurements are done.

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2. Canadian Air and Precipitation Monitoring Program,[1] January 1971

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 2), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports*.

Surface air and precipitation data for January 1971 are presented in table 2.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, January 1971

Station	Number of samples	Air surveillance, gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	4	0.1	0.0	0.1	83	2.00
Coral Harbour	4	.1	.1	.1	30	.68
Edmonton	4	.1	.0	.1	10	.53
Ft. Churchill	4	.1	.1	.1	40	.78
Fredericton	4	.1	.1	.1	18	.77
Goose Bay	4	.1	.0	.0	7	.62
Halifax	4	.1	.0	.1	15	1.33
Inuvik	3	.1	.1	.1	81	.84
Montreal	4	.1	.0	.1	11	.68
Moosonee	4	.1	.1	.1	8	.17
Ottawa	4	.1	.0	.1	12	.79
Quebec	3	.1	.0	.1	12	1.07
Regina	4	.1	.1	.1	19	.31
Resolute	1	.1	.1	.1	78	.14
St. John's, Nfld	3	.0	.0	.0	NS	NS
Saskatoon	4	.1	.1	.1	15	.39
Sault Ste. Marie	NS				9	.71
Thunder Bay	4	.1	.1	.1	88	2.10
Toronto	1	.0	.0	.0	NS	NS
Vancouver	4	.1	.0	.0	NS	NS
Whitehorse	4	.1	.1	.1	29	.42
Windsor	4	.1	.0	.0	19	.46
Winnipeg	4	.1	.1	.1	28	.40
Yellowknife	4	.1	.1	.1	24	.47
Network summary	83	0.1	0.0	0.1	31	0.75

NS, no sample.

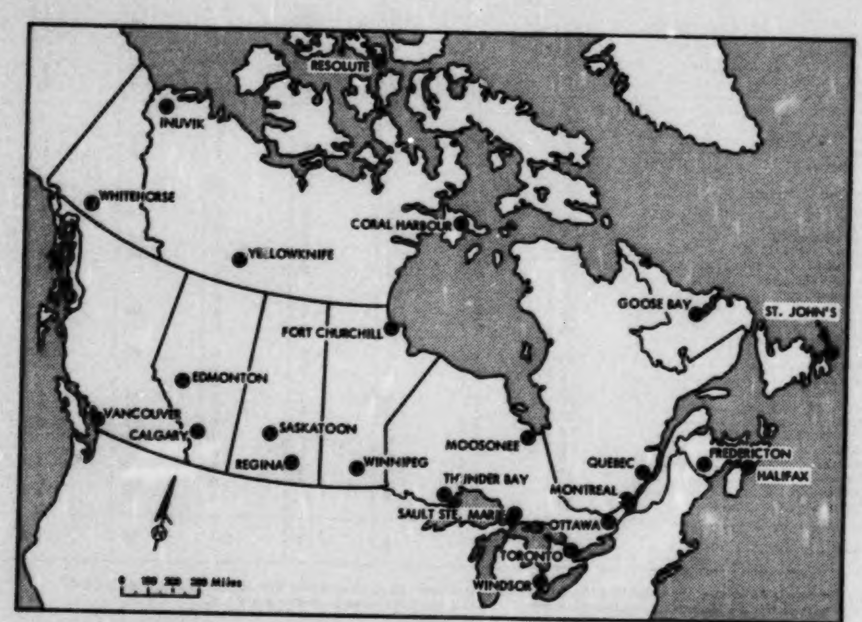
RESOLUTE
INUVIK
WHITEHORSE
CORAL HARBOUR
YELLOWKNIFE
GOOSE BAY
ST. JOHN'S
FORT CHURCHILL
EDMONTON
VANCOUVER
CALGARY
SASKATOON
MOOSONEE
REGINA
WINNIPEG
QUEBEC
FREDERICTON
HALIFAX
THUNDER BAY
MONTREAL
SAULT STE. MARIE
OTTAWA
TORONTO
WINDSOR
0 100 200 300 Miles

Figure 2. Canadian air and precipitation sampling stations

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[1] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

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3. Pan American Air Sampling Program January 1971

Pan American Health Organization and *Environmental Protection Agency*

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the Environmental Protection Agency (EPA) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 3. Analytical techniques were described in the March 1968 issue of *Radiological Health Data and Reports*. The January 1971 air monitoring results from the participating countries are given in table 3.

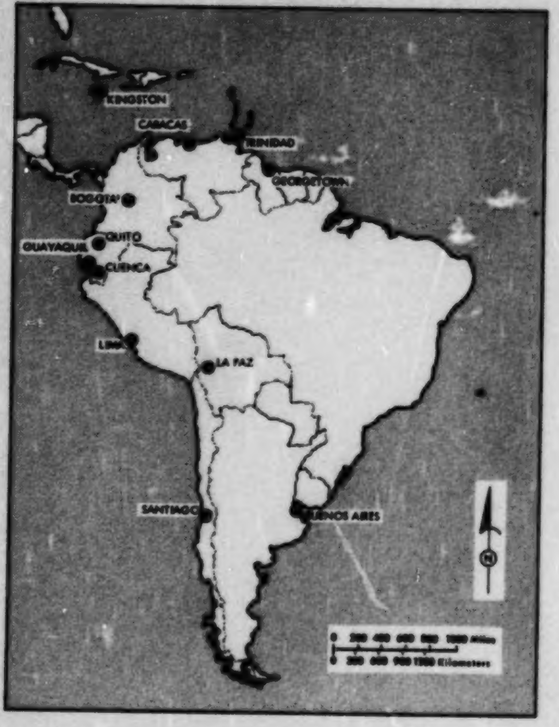

Figure 3. Pan American Air Sampling Program stations

Table 3. Summary of gross beta radioactivity in Pan American surface air, January 1971

Station location		Number of samples	Gross beta radioactivity (pCi/m³)		
			Maximum	Minimum	Average[a]
Argentina:	Buenos Aires	NS			
Bolivia:	La Paz	12	0.05	0.00	0.02
Chile:	Santiago	31	.36	.08	.21
Colombia:	Bogota	18	.06	.01	.03
Ecuador:	Cuenca	NS			
	Guayaquil	NS			
	Quito	NS			
Guyana:	Georgetown	4	.06	.02	.04
Jamaica:	Kingston	NS			
Peru:	Lima	30	.33	.02	.15
Venezuela:	Caracas	7	.08	.01	.03
West Indies:	Trinidad	15	.30	.01	.09
Pan American summary		107	0.36	0.00	0.11

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.

NS, no sample.

REFERENCES

(*1*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW-RP-3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(*2*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW-RP-4. Department of National Health and Welfare, Ottawa, Canada (December 1961).

(*3*) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW-RP-5. Department of National Health and Welfare, Ottawa, Canada (December 1962).

(*4*) BEALE, J. and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD-11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(*5*) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD-21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance, and environmental monitoring around nuclear facilities.

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1]

Summaries of the environmental radioactivity data follow for Argonne National Laboratory and Lawrence Radiation Laboratory.

1. Argonne National Laboratory
January–June 1970

University of Chicago
Lemont, Ill.

The radioactivity of the environment is determined on a continuing basis by measuring the radioactivity in naturally occurring materials collected both on and off the Argonne National Laboratory site. Since radioactivity is usually spread by air and water, the environmental monitoring program at Argonne has concentrated on these media. The sampling locations discussed in this report are shown in figures 1 and 2.

Air monitoring

The radioactivity of particulate matter in air was determined by drawing air through filter paper at a known rate and measuring the radioactivity of the particles collected by the paper. The samples were collected continuously at seven locations on the Argonne site and at five locations off the site. At one location on the site the filter paper was changed daily; at all other locations the filter papers were changed at weekly intervals. The daily samples record short-term changes in radioactivity, while the weekly samples are used to compare onsite and offsite activities. The alpha and beta radioactivity in air-filter samples are summarized in table 1; the average concentration of gamma-ray emitters as determined by gamma ray spectrometry are summarized in table 2. The alpha radioactivity concentrations were normal and in the range found in previous years. As in the past, much of the beta and gamma radioactivity was due to fission and neutron activation products from nuclear detonations, although about one-third of the gamma radioactivity and a smaller fraction of the beta radioactivity was due to beryllium-7, produced in the stratosphere by cosmic-ray interactions. The concentrations of total beta radioactivity and of all the gamma-ray emitters for which positive results were obtained, increased steadily from January to June. This variation was probably due to the increased stratospheric fallout usually observed in the spring. The absence of short-lived fission products early in the year and the sharp increase in 40-day half-life ruthenium-103 and 65-day half-life zirconium-95 in the spring imply that most of the fission products were pro-

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[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

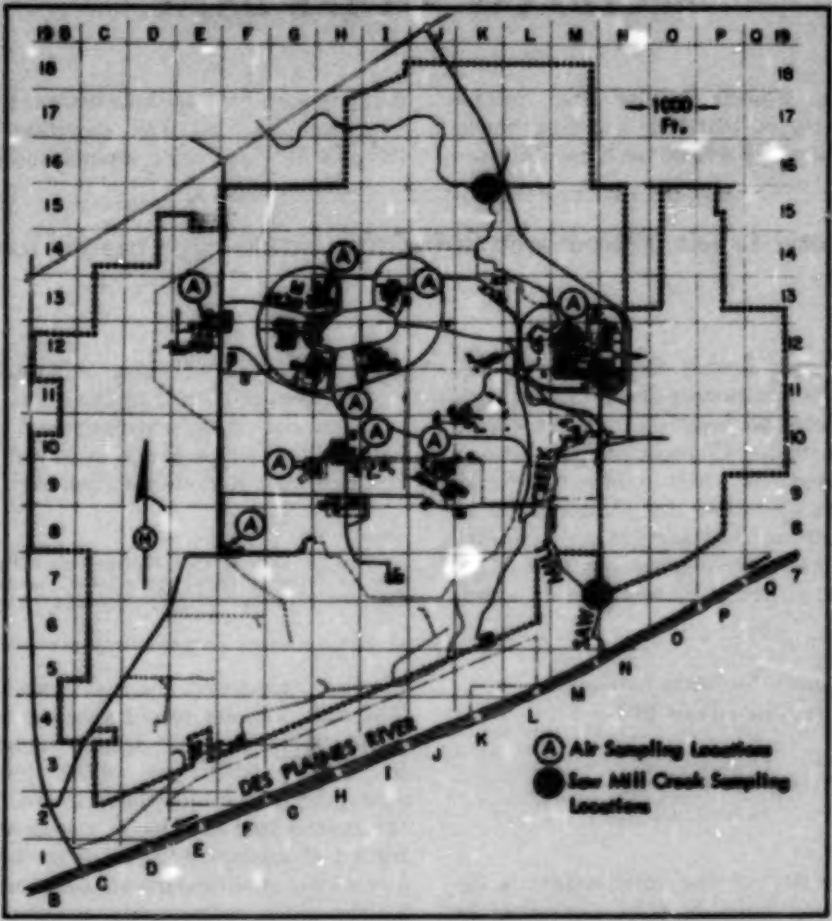

Figure 1. Onsite sampling locations at Argonne National Laboratory

Table 1. Alpha and beta radioactivity in air-filter samples[a]
Argonne National Laboratory, January–June 1970

Period (1970)	Location	Number of samples	Alpha radioactivity (fCi/m³)			Beta radioactivity (pCi/m³)		
			Average	Minimum	Maximum	Average	Minimum	Maximum
January	Onsite	27	3.2	1.1	10.6	0.08	0.03	0.11
	Offsite	17	3.2	1.2	8.2	.08	.03	.15
February	Onsite	22	3.0	1.1	4.4	.12	.08	.21
	Offsite	17	5.1	1.6	10.8	.14	.08	.20
March	Onsite	21	3.1	1.6	4.5	.17	.09	.30
	Offsite	22	3.7	2.0	9.0	.16	.08	.27
April	Onsite	22	3.1	2.2	6.7	.28	.16	.60
	Offsite	19	4.3	2.0	7.8	.31	.15	.61
May	Onsite	18	3.9	1.8	7.9	.46	.25	.60
	Offsite	23	6.6	1.9	12.7	.61	.18	1.16
June	Onsite	28	4.4	1.0	11.7	.63	.33	1.09
	Offsite	21	4.1	1.0	9.6	.61	.36	1.09
Summary	Onsite	137	3.4	1.0	11.7	0.29	0.03	1.09
	Offsite	119	4.6	1.0	12.7	0.31	0.03	1.16

[a] These results were obtained by measuring the samples 4 days after they were collected in order to avoid counting the natural radioactivity due to radon and thoron decay products.

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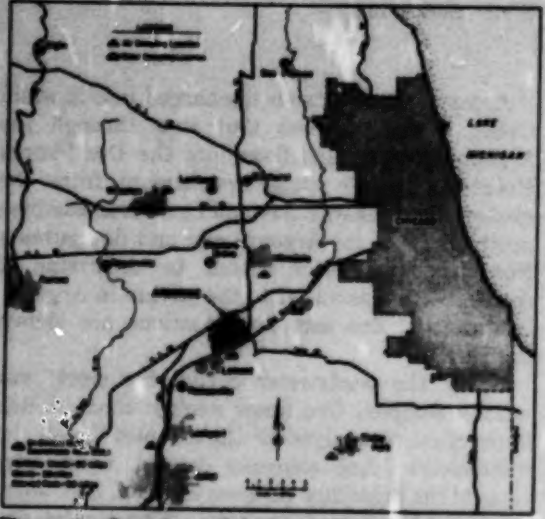

Figure 2. Location of Argonne National Laboratory (including some offsite sampling stations)

duced late in 1969 and were injected into the atmosphere at high altitudes. The average beta radioactivity for January–June 1970 was about 50 percent greater than in the corresponding period for 1969, primarily because of increased zirconium-niobium-95 concentrations.

The same fission products detected in the air filter samples were also present in precipitation samples, and the beta and gamma radioactivity in these samples also increased during the spring months. Composite large volume rain samples were also analyzed monthly for iron-55. The average monthly concentrations ranged from 3 to 400 pCi/m² of surface, about one-half of 1969 values. Iron-55 is a neutron activation product and was produced mainly in nuclear tests conducted in September and October 1961. Therefore, the above concentrations have been corrected for decay to October 15, 1961, for comparison purposes.

Air was also sampled continuously for radioiodine with activated charcoal in areas 200 and 300 because of the possibility of iodine releases in these areas. No iodine radioactivity was detected at either location.

Air sampling for argon-41 (a beta-particle emitter with a 1.8 hour half-life that is produced in an operating reactor by the action of neutrons on the stable argon-40 in air) was conducted near the Juggernaut reactor (Building 335) from January through April. On May 1, the reactor was shut down. The results are tabulated in table 3. These concentrations are based on 1-minute grab samples taken at a position downwind from the reactor at a point favorable for argon-41 detection after the reactor has been in operation for several hours. Therefore, the actual average concentrations in the vicinity of the reactor were much less than the values in the table.

Table 2. Gamma-ray radioactivity in air-filter samples
Argonne National Laboratory, January–June 1970

Radionuclide	Location	Concentration[a] (pCi/m³)						
		January	February	March	April	May	June	Summary
Barium-lanthanum-140	Onsite	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Offsite	< .01	< .01	< .01	< .01	< .01	< .01	< .01
Beryllium-7	Onsite	.06	.05	.09	.12	.10	.10	.09
	Offsite	.04	.09	.10	.09	.12	.09	.09
Cerium-141	Onsite	< .01	< .01	< .01	< .01	< .01	< .01	< .01
	Offsite	< .01	< .01	< .01	< .01	< .01	< .01	< .01
Cerium-144	Onsite	.01	.02	.03	.05	.09	.13	.05
	Offsite	.01	.03	.03	.06	.10	.12	.06
Cesium-137	Onsite	< .01	< .01	< .01	< .01	< .01	< .01	< .01
	Offsite	< .01	< .01	< .01	< .01	< .01	< .01	< .01
Iodine-131	Onsite	< .01	< .01	< .01	< .01	< .01	< .01	< .01
	Offsite	< .01	< .01	< .01	< .01	< .01	< .01	< .01
Ruthenium-103	Onsite	< .01	< .01	< .01	.01	.02	.02	.01
	Offsite	< .01	< .01	< .01	.01	.02	.02	.01
Ruthenium-rhodium-106	Onsite	.02	.02	.02	.04	.03	.03	.04
	Offsite	.03	.03	.03	.04	.07	.06	.05
Zirconium-niobium-95	Onsite	.01	.02	.04	.10	.15	.17	.06
	Offsite	.01	.03	.06	.12	.16	.17	.09

[a] For averaging purposes, individual sample results that were less than the minimum detectable concentration were assumed to be one half of the minimum detectable concentration.

Table 3. Argon-41 concentrations, near Juggernaut Reactor, January–April 1970[a]

Month (1970)	Number of samples	Number of samples >30 nCi/m³	Concentration[b] (nCi/m³)		Percent of AEC standard	
			Average	Maximum	Average	Maximum
January	32	6	26	153	66	383
February	32	7	30	334	75	834
March	32	11	25	85	63	213
April	25	7	20	79	50	198
Summary	121	31	25	334	63	834

[a] On May 1, the reactor was shut down.
[b] Minimum detectable concentration—30 nCi/m³.

Air was sampled for tritiated (hydrogen-3) water vapor, 50-yards west of the CP-5 reactor as well as 100-yards downwind from the reactor. Each sample was collected for a 24-hour period. The results are given in table 4. The results were positive in all cases, although the concentrations were well below the AEC standards. This nuclide is produced continuously while the reactor is in operation by the action of neutrons on the heavy water used for moderating and cooling. Occasional air samples were also collected 2,000 yards from the reactor to serve as controls. In these samples the tritium concentrations ranged from 7 to less than 2 pCi/m³. The average concentration for this period was 30 percent higher than during the first 6 months of 1969, but about 30 percent lower than the 1969 yearly average. Although the reactor has not been in operation since January 1969, the heavy water containing the long-lived tritium was handled while the reactor was undergoing modification, and small quantities evidently escaped from the building.

Table 4 Tritium concentrations near CP-5 reactor January–June 1970

Month (1970)	Number of samples	Concentration (pCi/m³)			Percent of AEC standard	
		Average	Minimum	Maximum	Average	Maximum
January	13	69	3	221	0.03	0.11
February	10	97	3	298	.05	.15
March	20	150	4	586	.08	.29
April	38	570	4	4,720	.29	2.37
May	35	360	9	2,530	.18	1.27
June	34	410	15	2,640	.21	1.32
Summary	151	270	3	4,720	0.14	2.37

Water monitoring

Argonne wastewater is discharged into Sawmill Creek, a small stream that runs through the Argonne grounds and flows into the Des Plaines River about 500 yards downstream from the wastewater discharge. Sawmill Creek was sampled upstream from the Argonne site and downstream from the wastewater outfall to determine if radioactivity was added to the stream in Argonne wastewater. The sampling locations are shown in figure 2.

Below the wastewater outfall the creek was usually sampled five times weekly. Since it was impractical to analyze all the samples for all the radionuclides and elements desired, equal portions of the individual samples collected each week were combined and analyzed. The results obtained in this way represent the average concentrations in the weekly samples. Above the site, samples were collected twice monthly and at least one sample each month was analyzed for each radionuclide of interest. The total alpha and beta radioactivities found in Sawmill Creek during January–June 1970 are given in table 5. Upstream from the Argonne site, the alpha activity was due primarily to radioactive nuclides that occur naturally in the stream. Any additional activity downstream would indicate a detectable contribution from Argonne wastewater. The results show that Argonne wastewater did not increase the alpha radioactivity in Sawmill Creek, and on some days the wastewater evidently contained less alpha radioactivity than upstream water.

The alpha-particle emitters most likely to be present in Argonne wastewater are isotopes of uranium, plutonium, and thorium. The alpha radioactivity in the creek water due to these elements is summarized in table 6. The concentrations were normal at both locations and low compared to the AEC standards. Comparison of these concentrations with the total alpha radioactivity indicates that most of the alpha activity in the creek was due to uranium. Based on the uranium concentrations at both locations and on a dilution factor of 8 for wastewater into the creek, the uranium content of the wastewater averaged about 3.2 pCi/liter during this period.

In addition to the natural beta radioactivity

Table 5. Nonvolatile alpha and beta radioactivity in Sawmill Creek water Argonne National Laboratory, January–June 1970

Month	Location[a]	Number of samples	Alpha radioactivity (pCi/liter)			Beta radioactivity (pCi/liter)		
			Average	Minimum	Maximum	Average	Minimum	Maximum
January	Upstream	2	2.9	2.7	3.2	26	25	27
	Downstream	19	2.9	2.5	3.6	15	10	20
February	Upstream	2	4.1	3.1	5.1	10	8.1	12
	Downstream	20	2.2	1.7	2.8	13	10	17
March	Upstream	2	2.5	2.2	2.7	17	15	18
	Downstream	18	1.4	.4	3.0	16	11	27
April	Upstream	2	1.8	.8	2.8	11	10	12
	Downstream	19	1.8	1.4	3.0	10	7.8	13
May	Upstream	2	1.5	1.5	1.6	12	10	14
	Downstream	24	2.1	1.2	2.6	14	10	17
June	Upstream	2	2.1	2.1	2.2	19	18	20
	Downstream	20	1.4	1.0	1.8	14	12	17
January–June summary	Upstream	12	2.5	0.8	5.1	16	8.1	27
	Downstream	120	2.0	.4	3.6	14	7.8	27

[a] Relative sampling location with respect to Argonne wastewater outfall (figure 1).

Table 6. Alpha-emitting elements in Sawmill Creek water Argonne National Laboratory, January–June 1970

Element	Location[a]	Number of samples	Concentration[b] (pCi/liter)			Percent of AEC standard[c]	
			Average	Minimum	Maximum	Average	Maximum
Uranium	Upstream	6	1.7	0.7	2.6	0.004	0.007
	Downstream	58	1.9	.9	3.2	.005	.008
Plutonium	Upstream	6	—	—	<.05	—	<.001
	Downstream	57	—	—	<.05	—	<.001
Thorium	Upstream	6	<.05	<.05	.07	<.003	.004
	Downstream	57	<.05	<.05	.07	<.003	.004

[a] Relative sampling location with respect to Argonne wastewater outfall (figure 1).

[b] For averaging purposes, individual sample results that were less than the minimum detectable concentration were assumed to be one half of the minimum detectable concentration.

[c] Standards are: uranium-238, 40 nCi/liter; plutonium-239 (soluble), 5 nCi/liter; thorium-232 (soluble), 2 nCi/liter.

Table 7. Beta-emitting radionuclides in Sawmill Creek water Argonne National Laboratory, January–June 1970

Radionuclide	Location[a]	Number of samples	Beta radioactivity[b] (pCi/liter)			Percent of AEC standard	
			Average	Minimum	Maximum	Average	Maximum
Barium-140	Upstream	6	—	—	< 2	—	<0.007
	Downstream	60	—	—	< 2	—	< .007
Cerium-144	Upstream	12	—	—	<10	—	< .1
	Downstream	120	—	—	<10	—	< .1
Cesium-137	Upstream	4	—	—	< .5	—	< .003
	Downstream	78	<0.5	<0.5	2.2	<.0003	.011
Cobalt-58	Upstream	12	—	—	< 5	—	< .005
	Downstream	120	—	—	< 5	—	< .005
Cobalt-60	Upstream	12	—	—	< 3	—	< .006
	Downstream	120	—	—	< 3	—	< .006
Tritium	Upstream	6	560	440	920	.019	.031
	Downstream	120	1,310	440	9,970	.044	.33
Iodine-131	Upstream	0	—	—	—	—	—
	Downstream	120	—	—	< 3	—	<1
Strontium-89	Upstream	6	—	—	< 2	—	< .07
	Downstream	60	—	—	< 2	—	< .07
Strontium-90	Upstream	6	1.9	.5	3.6	.6	1.2
	Downstream	60	1.4	.6	2.1	.5	.7
Technetium-99	Upstream	4	—	—	< .5	—	<.0002
	Downstream	78	—	—	< .5	—	<.0002
Thorium-protactinium-234	Upstream	6	1.4	.6	2.1	.007	.011
	Downstream	58	1.5	.7	2.6	.008	.013

[a] Relative sampling location with respect to Argonne wastewater outfall (figure 1).

[b] For averaging purposes, individual sample results that were less than the minimum detectable concentration were assumed to be one half of the minimum detectable concentration.

in the creek, beta radioactivity from nuclear detonations was detected at both sampling locations and beta radioactivity from Argonne wastewater was found in some samples below the outfall. The normal beta radioactivity is approximately 5 pCi/liter above the site and 3 to 5 pCi/liter below the site, depending on the relative amounts of creek and wastewater. The Argonne contribution to the total nonvolatile beta radioactivity below the outfall during the first half of 1970 is estimated to be approximately 2 pCi/liter, about the same as in 1969. The remaining activity at both locations, 8 to 10 pCi/liter, was due to the fallout and naturally-occurring radioactivity. The fallout level was about the same as during 1969.

The results of analysis of Sawmill Creek water for specific beta-emitting nuclides are summarized in table 7. The principal beta-particle emitter added to the creek by Argonne wastewater was tritium. The wastewater increased the tritium content of the Creek by about a factor of two. This radionuclide, present as water (HTO), is not included in the total beta radioactivity in table 5 because this activity is determined by evaporating the water and measuring the nonvolatile residue. Separate samples were analyzed specifically for tritium. Although small amounts are produced by cosmic-ray interactions with the atmosphere, the bulk of the tritium in above-site water originated in nuclear detonations. Although some of the other nuclides listed were also added to the creek by fallout, the total concentration, regardless of source, must be used in assessing the health hazard of a radioactive nuclide not naturally present in the environment. The percent of the AEC standard given in the table was calculated on this basis. As indicated in the table, the beta radioactivities in the creek were very low compared to the AEC standards.

Since Sawmill Creek empties into the Des Plaines River, which in turn flows into the Illinois River, the radioactivity in the latter two streams is important in assessing the contribution of Argonne wastewater to the environmental radioactivity. The Des Plaines River was sampled monthly above the mouth of Sawmill Creek and weekly below the mouth to determine if the radioactivity in the creek has any effect on the radioactivity in the river. The total radioactivity is summarized in table 8, and the results of analysis for specific elements and radionuclides are given in table 9. Tritium was the only nuclide whose concentration was higher below the mouth of Sawmill Creek, and the additional activity at this location evidently originated in Argonne wastewater. However, the average and maximum concentrations below the creek amounted to only 0.02 and 0.05 percent, respectively, of the AEC standards. The concentration of tritium in the river above the creek is similar to that found

Table 8. Average radioactivity in Des Plaines and Illinois River water, Argonne National Laboratory January–June 1970

Location	Concentration (pCi/liter)			
	Nonvolatile alpha radioactivity	Uranium	Nonvolatile beta radioactivity	Tritium
Des Plaines River[a] (above Sawmill Creek)	[b] 2.8 (6)	—	16 (6)	630 (3)
Des Plaines River[b,c] (below Sawmill Creek)	3.1 (25)	2.1 (6)	16 (25)	710 (21)
Illinois River[d]	1.9	1.5	10	—

[a] Sampled near Route 45, upstream from the mouth of Sawmill Creek.

[b] Number in parenthesis is number of samples.

[c] Sampled near Lemont, downstream from the mouth of Sawmill Creek.

[d] Sample collected on June 11 at McKinley Woods opposite the Dresden Nuclear Power Plant.

Table 9. Radioactivity in Des Plaines River water Argonne National Laboratory, January–June 1970

Radionuclide	Location[a]	Number of samples	Concentration[b] (pCi/liter)		
			Average	Minimum	Maximum
Barium - lanthanum-140	Upstream	3	—	—	< 2
	Downstream	6	—	—	< 2
Cerium-144	Upstream	6	—	—	<10
	Downstream	25	—	—	<10
Cobalt-58,-60	Upstream	6	—	—	<10
	Downstream	25	—	—	<10
Tritium	Upstream	3	630	580	670
	Downstream	21	710	<400	1,640
Plutonium (alpha)	Upstream	3	—	—	< .05
	Downstream	7	—	—	< .05
Strontium-89	Upstream	3	—	—	< 2
	Downstream	6	—	—	< 2
Strontium-90	Upstream	3	1.7	1.1	2.4
	Downstream	6	1.5	< .5	2.4
Thorium (alpha)	Upstream	3	—	—	< .05
	Downstream	7	—	—	< .05
Thorium - protactinium-234	Upstream	—	—	—	—
	Downstream	6	1.7	1.0	2.6
Uranium (alpha)	Upstream	—	—	—	—
	Downstream	6	2.1	1.4	3.3

[a] Relative sampling location with respect to Argonne wastewater outfall (figure 1).

[b] For averaging purposes, individual sample results that were less than the minimum detectable concentration were assumed to be one half of the minimum detectable concentration.

last year in the Des Plaines River and to that found in other streams in the area. Below the mouth of the creek, the concentration decreased to one-third of the 1969 average.

The concentrations of the other radionuclides and the total alpha and beta radioactivities were in their normal ranges at both locations. The annual average beta radioactivity was about the same as in 1969. The natural nonvolatile beta radioactivity in the river is 5 to 10 pCi/liter, and the excess (about 7 pCi/liter) was attributed to fallout. The total radicactivity in samples of Illinois River water were normal and similar to that found in other streams in the area. No evidence of radioactivity from Argonne was detected.

Radioactivity in milk

Raw milk was collected monthly from a local dairy farm and analyzed for several fission products. Strontium-89, iodine-131, and barium-140 were not present in concentrations greater than the minimum detectable amounts of 20 pCi/liter for iodine-131, and 3 pCi/liter for the other two radionuclides. The strontium-90 and cesium-137 concentrations are given in table 10. These two radionuclides are long-lived fission products from past nuclear tests and their presence in milk is not related to Argonne operations. The strontium-90 and cesium-137 concentrations during the first half of 1970 were nearly unchanged from the corresponding period of 1969.

Table 10. Fission product concentration in milk January–June 1970

Date collected	Concentrations (pCi/liter)	
	Cesium-137	Strontium-90
January 6	18	1.8
February 3	10	4.1
March 3	18	6.6
April 8	23	6.5
May 6	18	7.2
June 3	27	9.8
Average	19	6.0

Conclusion

Argonne's contribution to the environmental radioactivity was primarily limited to tritium and argon-41 in the air and to tritium in water from Sawmill Creek and the Des Plaines River. The only activity detected off the site were the low levels of tritium in the two streams.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January—June 1969	July 1970
July—December 1969	January 1971

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2. Lawrence Radiation Laboratory[2]
January–June 1970

University of California
Berkeley, Calif.

Berkeley site

The Berkeley site of the Lawrence Radiation Laboratory (LRL) is situated on the western slope of the range of hills running along the eastern side of San Francisco Bay. The laboratory area is largely separate from the main campus of the University (figure 3).

To the north and south of the laboratory area are residential areas of the cities of Berkeley and Oakland. The Berkeley campus of the University of California is on the west; to the east are the Lawrence Hall of Science and the Space Sciences Laboratory, beyond them lies uninhabited watershed land and the Tilden Regional Park.

The most prevalent wind direction is westerly. During the summer months, the afternoon sea breeze establishes a very pronounced prevailing westerly wind direction. At other times, the direction is less predictable. Annual rainfall is 23 inches, almost all of which falls between November 1 and May 1. The prevailing wind direction during precipitation is southerly.

The laboratory carries on a wide ranging program of general research in the fields of both physical and biological sciences. Facilities include a number of large accelerators and various

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[2] Summarized from "Results of Environmental Radioactivity Sampling Program, January–June 1970," Lawrence Radiation Laboratory, Livermore and Berkeley, Calif.

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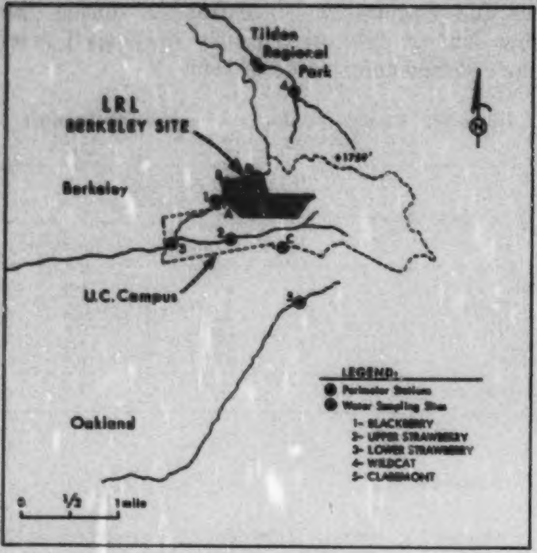

Figure 3. Environmental sampling locations at the Berkeley site, Lawrence Radiation Laboratory

physics, chemistry, biology, and medical research laboratories.

The basic policy at LRL has long been to prevent, as far as possible, any release of radioactive material to the environment, no matter how small. No deliberate releases are sanctioned, except where no practical method for containment has yet been developed, and quantities are small compared with standards established by the International Commission on Radiological Protection (ICRP) and the Atomic Energy Commission (AEC).

The most sensitive measurements of releases are those taken closest to the source itself, before dilution makes detection of small quantities more difficult. The stack sampling program, therefore, provides the most useful information for controlling releases to the atmosphere. Over 100 separate exhausts from hoods and glove-box manifolds are sampled. The total quantity released from these stacks during January–June 1970 was 320 nCi of alpha radioactivity, 7.4 Ci of carbon-14, 49 Ci of tritium and 52 μCi of other beta-particle emitters. The average concentrations in the total exhaust, before any dilution by the atmosphere, was 46 percent of the maximum permissible concentration for offsite breathing zone air, as given by the ICRP.

In addition to the careful sampling of stacks, an environmental air sampling program is also carried on to make sure no undetected releases occur. These samples provide a direct measurement of possible exposure to the nearby population. The sampling stations designated "local area" are scattered around the site and provide samples of the atmosphere on the site itself. The "perimeter" samples are taken at the boundary line of University property, in the direction of populated areas. From the results of these samples, there appears to have been no significant exposure from radioactive materials released by LRL. The levels of radioactivity observed in each type of sample are presented in table 11.

Table 11. Atmospheric monitoring, LRL Berkeley site January–June 1970

Sampling locations (number of locations)	Number of samples	Average concentration (pCi/m^3)			
		Alpha radioactivity		Beta radioactivity	
		Average	Maximum	Average	Maximum
Local area (10)	246	0.000	0.005	0.30	1.36
Perimeter					
A	25	.000	<.005	.30	.70
B	23	.000	<.005	.31	.74
C	22	.000	<.005	.32	.74
D	24	.000	<.005	.33	.69
Summary	94	.000	<.005	.32	.74

At each of these environmental stations, rain or dry fallout is also collected. Open 15-inch-diameter polyethylene bags form the collecting vessel. If no rain has fallen, the bags are rinsed out with dilute nitric acid to obtain a sample. Since, on the average, the more remote perimeter stations show about the same radioactivity as the nearer ones, the radioactivity does not result from laboratory operations. The radioactivity levels in samples collected at each location are summarized in table 12.

Table 12. Total deposition, LRL Berkeley site January–June 1970

Sampling locations (number of locations)	Number of samples	Average deposition (nCi/m^2)			
		Alpha radioactivity		Beta radioactivity	
		Average	Maximum	Average	Maximum
Local area (9)	54	0.023	0.073	4.58	5.36
Perimeter (4)	24	.035	.066	5.31	6.45

Table 13. Summary of sewer data, LRL Berkeley site, January–June 1970

Sewer	Total quantities discharged 6 months			Number of samples	Net concentrations (pCi/liter)			
	Total volume (Ml)	Total alpha radioactivity (μCi)	Total beta radioactivity (mCi)		Alpha		Beta	
					Average	Maximum	Average	Maximum
Hearst Sewer	231.6	0	8.49	23	0	1.1	36.7	147
Strawberry Sewer	35.3	76.6	.73	19	2.17	18.8	20.7	136
Summary	266.9	76.6	9.22	42	0.20	18.8	34.6	147

All liquid waste known to be radioactive is collected, solidified, and shipped away. Other liquid wastes are discharged directly to the municipal sewer system. Occasionally, small quantities of radioisotopes are accidentally released to the sewer system. There are two outfalls, each of which is monitored by a continuous proportional sampling system to insure that no significant quantities have been discharged (table 13). The total concentration (alpha-plus-beta radioactivity) in sewage is only 38 percent of the standard for drinking water and therefore does not constitute an exposure threat. A sizeable fraction of the measured beta concentration is the naturally occurring isotope, potassium-40, from human wastes and chemicals.

The storm drainage from the laboratory flows into the surface stream system. These surface streams are exposed as they run through the University property and are sampled at three places. Results are listed as "onsite streams" in table 14. Two nearby offsite streams are also sampled to provide a comparison. All concentrations are less than the standard for drinking water. The results from the water sampling program are presented in table 14.

Neutron and gamma-ray fields are measured at each of the four perimeter stations as well as at several locations within the site. Background measurements are obtained from a leased building used as a low-level counting room in downtown Berkeley. This building is remote from the main LRL site and measurements are not influenced by accelerator operations.

At each station, gamma measurements are made by a recording G-M detector, standardized with a calibrated radium source. These instruments operate unattended and each can operate for 1 week on its internal battery should external power fail.

Table 14. Water monitoring, LRL Berkeley site January–June 1970

Type and source of sample	Number of samples	Concentration (pCi/liter)			
		Alpha radioactivity		Beta radioactivity	
		Average	Maximum	Average	Maximum
Surface water:					
Onsite streams:					
Blackberry	25	0.30	1.6	2.4	7.0
Lower Strawberry	25	.60	4.9	7.8	30
Upper Strawberry	25	.30	4.4	3.2	8.4
Summary	75	.40	4.9	4.5	30
Offsite streams:					
Claremont	25	1.3	12.1	2.8	14
Wildcat	25	.00	1.1	3.0	25
Summary	50	.63	12.1	2.8	25
Tap water	24	.042	.28	1.6	2.9

Several neutron detectors are employed at each station. The primary detector is a BF_3 gas proportional counter in a 2½ inch-thick paraffin-lined moderator. This detector is sensitive in the region from 0.1 to 20 MeV, where 75 percent of the biologically significant neutrons exist. A polyethylene-lined proton recoil neutron detector provides a measure of the energy flux density. The ratio of energy flux density to neutron flux density gives the average neutron energy which allows conversion of the data to dose in rems. Cobalt disks in moderators are maintained as long-term integrating neutron monitors at many sites throughout the laboratory as well as at each perimeter station.

Cosmic ray intensity is continuously monitored by a meson detector with an effective angle of acceptance of 2.3 steradians (in the upward direction). This provides information on the background neutron levels contributed by cosmic rays.

At each station, total radiation levels are well below the standards set for the general public by the ICRP and the National Council on Radiation Protection and Measurements (NCRP). Results are presented in table 15.

Table 15. Beta-gamma and fast neutron surveillance results, Berkeley site, January–June 1970

Station	Total beta-gamma exposure (mrem) (background subtracted)	Total fast neutron exposure[a] (mrem) (background subtracted)
A	12.9	93.5
B	7.1	33.7
C	4.5	.44
D	5.8	33.8
Downtown Berkeley	([b])	([b])

[a] 2.45×10^7 n/cm^2 = 1 rem.
[b] Detector not in service.

Livermore site

The Livermore site of LRL (figure 4) is located in the Livermore Valley midway between the Pacific coast and the San Joaquin Valley in northern California, approximately 50 miles southeast of San Francisco. Shielded from the ocean by the western hills, the Livermore Valley has a warm, dry climate. Annual rainfall is about 14 inches and the relative humidity is about 30 percent during the summer months and about 40–50 percent the remainder of the year. Prevailing winds are from the west, but inversions are frequent during the night.

Agriculture is the principal activity in the Livermore Valley. Roses, grain, hay, and grapes are the major products. Several cattle and sheep ranches surround the Livermore site.

The Livermore site comprises an area of 1-square mile, approximately 3 miles east of the city of Livermore. Livermore and Pleasanton, with a combined population of 45,000, are the populated areas of primary interest to the Livermore site.

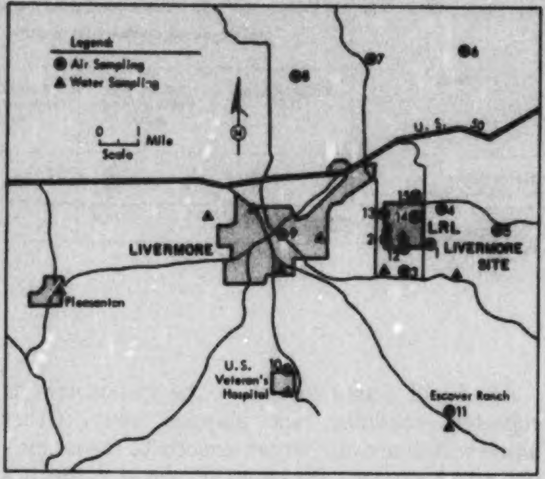

Figure 4. Environmental sampling locations at the Livermore site, Lawrence Radiation Laboratory

An environmental sampling program is maintained to provide information regarding the effectiveness of control measures and to determine whether any radiological changes in the environment are the result of laboratory operations. The sampling program includes air particulates, soil, domestic water, sewer effluent, sewage plant products, milk, and vegetation. The milk samples are obtained from one dairy in the Livermore Valley and from another dairy near Site 300.

Techniques

An automated counting system is used for all environmental air samples. This system utilizes gas-flow proportional detectors for both alpha and beta counting. The alpha detector is approximately 11 percent efficient for the 5.1 MeV alphas of plutonium-239. The efficiency for the 0.54 MeV and 2.27 MeV betas of strontium-90 in equilibrium with yttrium-90 is about 26 percent.

Soil, water, and sewage samples are counted on an automatic low-background system that detects alpha particles with an efficiency of about 34 percent at 5.1 MeV, strontium-yttrium-90 beta particles with an efficiency of approximately 50 percent.

The milk samples are concentrated using a vacuum-operated, foam-entrainment evaporator so that about 9 liters of whole milk are condensed to 2 liters by evaporation. The sample is counted in a plexiglass container placed between two 20-by 10-cm NaI (Tl) crystals. The data are recorded in a multi-channel analyzer and

Table 16. Airborne particulate radioactivity around LRL-Livermore site January–June 1970

Sampling location	Number of samples	Alpha radioactivity[a] (fCi/m³)		Beta radioactivity[a] (fCi/m³)	
		Average	Maximum	Average	Maximum
1	36	≤0.4	1.3	169	452
2	30	≤ .4	≤ .4	101	417
3	24	≤1.0	≤1.0	80	202
4	23	≤1.0	≤1.0	152	278
5	24	≤1.0	≤1.0	114	274
6[b]	–				
7	25	≤1.0	≤1.0	97	255
8	23	≤1.0	≤1.0	81	184
9	23	≤1.0	≤1.0	155	417
10	21	≤1.0	≤1.0	71	190
11	22	≤1.0	≤1.0	72	190
12	36	≤ .4	2.1	212	626
13	38	≤ .4	1.2	156	450
14	36	≤ .4	≤ .4	182	488
15	39	≤ .4	1.3	186	524
16	23	≤1.0	≤1.0	131	514

[a] Approximate limits of sensitivity: Alpha
locations 1, 2, 12–15—4 fCi/m³
locations 3–11, 16—1.0 fCi/m³
Beta
locations 1, 2, 12–15—4 fCi/m³
locations 3–11, 16—10 fCi/m³
Estimated error limits: Alpha radioactivity ± 30 percent
Beta radioactivity ± 20 percent.

[b] Sampler is being relocated.

processed by a computer code using standard spectra taken on the same counting apparatus.

The vegetation samples, taken from nine locations throughout the Livermore Valley, are dried in ambient air for about 1 week. Then, 150–200 grams of dry material are pressed into a pellet, 13 cm diameter by 1.3 to 2.6 cm thick. The pellet is then counted on the system described for milk. The data are also processed by computer.

Samples of environmental water, milk, and vegetation are analyzed for tritium. One milliliter of water or distillate is counted in a liquid scintillation counter having a 32 percent efficiency for HTO.

The soil samples are prepared by digesting 1 gram of material in a mixture of perchloric and nitric acids and evaporating to near dryness. The resulting residue is redissolved in a hydrogen peroxide and nitric acid mixture and subsequently plated onto stainless-steel plates. The water and sewage samples, of one-half liter volume, are treated similarly.

Air and soil samples are collected to ascertain that control efforts are restricting the release of radioactivity from the laboratory to levels that do not exceed the permissible levels for the neighborhood around an atomic energy facility. The water samples are collected to ascertain that radioactivity is not entering the underground water supply which provides most of the domestic water for the cities of Livermore and Pleasanton, the sole supply for ranches in the Livermore and Amador Valleys. Samples were taken at the Livermore Sewage Disposal Plant to establish that liquid effluent from the laboratory is not contributing significant radioactivity to the dried sludge or liquid effluent produced. The dried sludge is used as an agricultural soil conditioner. Some liquid effluent released to the Los Positas Arroyo is used for irrigation of the golf course turf and some agricultural land.

Air samples are collected continuously at 15 sites within 5 miles of the laboratory. Samples are collected at a rate of 4 cfm on 100-square centimeter HV-70 filter papers, which are changed after every 7 days of operation. A minimum decay period of 4 days is observed before the samples are counted to eliminate the effect of natural radon and thoron daughters (table 16). The average airborne beta radioactivity was 0.1 pCi/m³, about the same as that reported during the previous 6 months.

The measurement of low level "background" radiation was accomplished with thermolumines-

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cent dosimeters located at nine points on the site perimeter and at three offsite locations. The limit of detection for these dosimeters is 10 mR. The three offsite locations had dose recordings of 10 mR for the past 6 month period. At the nine locations around the controlled area perimeter, doses of 10 mR were recorded at all the locations except locations 3 and 5 (table 17).

Table 17. External gamma radiation measurements LRL Livermore site, January–June 1970

Dosimeter location[a]	Exposure (mR)
1	10
2	10
3	24
4	10
5	35
6	10
7	10
8	10
9	10
10	10
11	10
12	10

[a] Locations 1-9—controlled area perimeter.
Locations 10, 11, and 12—uncontrolled area.

Domestic water samples were collected monthly from nine nearby sources. No samples showed an alpha radioactivity above the limit of detection (5.0 pCi/liter). The beta radioactivity is shown in table 18. The tritium concentrations in water samples were below the limit of detection (5 nCi/liter).

Table 18. Beta radioactivity in domestic water supplies, LRL Livermore site, January–June 1970

Dosimeter location	Beta radioactivity[a] (pCi/liter)	
	Maximum	Average
1	7.2	1.9
2	10.9	4.7
3	9.1	2.3
4	7.2	1.8
5	4.5	1.9
6	1.8	1.8
10	20.5	4.2
Building 254 (LRL)	20.4	6.4
Building 419 (LRL)	42.3	9.6

[a] The limit of detection for gross beta radioactivity is 1.8 pCi/liter.

Samples were collected daily at the laboratory sewer discharge. The results of the analyses of these samples are given in table 19. The average alpha radioactivity concentration in the sewer effluent ranged between 3.5 and 20 pCi/liter, while the monthly average beta radioactivity varied between 130 and 760 pCi/liter. The average tritium content of the effluent ranged between 11 and 160 nCi/liter with a maximum of 1,800 nCi/liter. The effluent was also analyzed for strontium-90, radium-226, -228, and iodine radioisotopes.

Table 19. Radioactivity in laboratory sewer effluent samples, January–June 1[illegible]

Month (1970)	Alpha radioactivity (pCi/liter)		Beta radioactivity (pCi/liter)		Tritium (nCi/liter)		Average concentrations			
	Maximum	Average	Maximum	Average	Maximum	Average	Strontium-90 (pCi/liter)	Radium-226 (fCi/liter)	Radium-228 (pCi/liter)	Mixed iodine (pCi/liter)
January	51	7.6	2,300	452	100	18	37	49	8.6	7.7
February	56	7.0	3,350	560	64	11	49	75	11	13.5
March	43	4.6	1,120	260	1,180	160	6.2	51	1.3	18.5
April	15	3.5	585	130	580	41	6.9	49	1.5	.4
May	280	20	8,000	760	590	51	36	66	1.7	1
June	64	20	705	183	41	25	2.9	29	12	1

Table 20. Radioactivity in samples from the Livermore Sewage Disposal Plant, January–June 1970

Month (1970)	Gross alpha radioactivity (pCi/liter)						Gross beta radioactivity (pCi/liter)					
	Digesters		Aeration tank		Effluent		Digesters		Aeration tank		Effluent	
	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average
January	440	323	62	32	<5	<5	7,780	3,060	370	240	77	27
February	475	240	75	57	<5	<5	5,110	2,510	540	328	127	55
March	381	182	65	35	<5	<5	2,810	2,040	4,140	1,240	110	46
April	334	190	67	30	<5	<5	3,120	1,890	263	175	180	40
May	358	249	83	55	<5	<5	6,780	3,860	1,140	697	2,060	271
June	457	262	248	136	<5	<5	3,060	2,090	540	452	79	59

When the sewage from the laboratory and city of Livermore enters the sewage disposal plant, the liquid and sludge are separated. The sludge passes into one of two digesters where it is broken down by bacterial action. Methane gas is evolved and burned, and the remaining sludge is released to large sludge lagoons and/or drying beds and is retained for subsequent possible use as a soil conditioner. The purified water is used on the Livermore golf course and for agricultural irrigation on a nearby farm; the excess is discharged into the Los Positas Arroyo. Samples were collected weekly from the aeration tanks, each digester, and the effluent to the arroyo. The results of these analyses are given in table 20.

Samples of top-layer soil are collected quarterly at the 19 sampling locations in the Livermore Valley. The alpha radioactivity of each sample was less than the limit of detection (1.5 pCi/g). The beta radioactivity fluctuated from the limit of detection (3.5 pCi/g) to 15.5 pCi/g, averaging 5.4 pCi/g. The concentrations detected are within the normal range for soil in the Livermore Valley, as determined from surveillance during previous years.

Average radioactivity levels in monthly milk samples from the dairy near the Livermore site were 5.1 pCi/liter of cesium-137, 8.9 nCi/liter for tritium, and no detectable concentrations of cerium-141,-144. For the dairy near Site 300, the average concentrations were 1.4 pCi/liter, 8.8 nCi/liter and undetectable for cesium-137, tritium, and cerium-141,-144, respectively.

Vegetation samples were collected during January–June of 1970. The radioactivity of 15 unwashed grass samples and three eucalyptus leaf samples is presented in table 21. A portion of each sample was freeze-dried, and the water collected was analyzed for HTO.

Continuous radioactive air sampling is maintained on the effluent from stacks of operations that are potential sources of radioactive material releases. These facilities include the hot cells, transuranic chemistry, plutonium metallurgy, and the reactor building. The effluent from these buildings passes through an absolute filter prior to being exhausted to the atmosphere. Analysis of samples from the stack monitoring system indicates that the permissible offsite concentrations were not exceeded as a result of stack effluent during the past 6 months. The radioactivity in the environment remained below the appropriate AEC concentration guide levels. The gross alpha and beta radioactivities contained in samples of airborne particulate debris, soil, water, and sewage leaving the laboratory were at the levels normally observed for these samples. The milk and vegetation samples showed no gamma-emitting radionuclides other than those present in the current worldwide fallout inventory. Their activities were similar to those normally observed for these nuclides. The stack sampling program indicated that laboratory operations did not contribute any of significant quantities of radioactivity to the environment. The data indicated the LRL radiological control measures were successful in preventing significant contribution of radioactive material to the environment around the laboratory site during this period.

Table 21. Radioactivity in vegetation, LRL Livermore site, January–June 1970

Nuclide	Concentration[a] (pCi/g dry weight)				Limit of detection
	Grass		Eucalyptus leaves		
	Average	Maximum	Average	Maximum	
Beryllium 7	≤0.01	≤0.01	≤0.01	≤0.01	0.01
Manganese-54	.05	.10	.02	.03	.01
Zirconium-95	.53	.90	.10	.16	.01
Ruthenium-103, -106	.33	.04	.06	.06	.02
Antimony-125	.15	.38	.06	.10	.02
Cesium-137	≤ .01	≤ .01	≤ .01	≤ .01	.01
Cerium-141,-144	1.17	2.86	.34	.40	.02
Tritium[a]	≤5	8.3	<5	<5	5

[a] Except tritium which is in nCi/liter of water.

Site 300

The high explosive test area at Site 300 (figure 5) covers 10 square miles in the hills in a very sparsely populated ranching area about 15 miles southeast of Livermore and 8 miles southwest of Tracy. The chief area of concern for Site 300 is Tracy with a population of about 15,000. Air and water samples are taken to determine whether operations at Site 300 are changing the normal radioactivity levels in the vicinity. The 11 air samplers at Site 300 are operated on a continuous basis at about 50 cfm, and the filter papers are changed regularly. Most of these air samplers are

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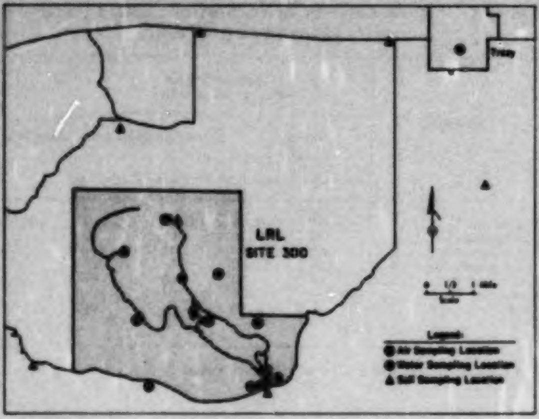

Figure 5. Sampling locations at Site 300, LRL

located within the boundaries of the test site due to unavailability of electric power facilities offsite. Table 22 gives the airborne particulate radioactivity for January–June 1970. Water samples are collected monthly from onsite wells. Streams in the area are sampled when they contain water (usually during the winter). No sample showed an alpha radioactivity concentration above the limit of detection (5.0 pCi/liter). The average beta concentrations ranged from 2.3 pCi/liter to 8.3 pCi/liter, with a maximum single sample concentration of 16.3 pCi/liter.

Soil samples are collected quarterly at nine offsite locations. The alpha radioactivity ranged from 1.5 pCi/g (the limit of detection) to 1.9 pCi/g. The beta radioactivity ranged from the limit of detection (3.5 pCi/g) to 16 pCi/g, with an average activity of 7.9 pCi/g.

Table 22. Airborne particulate radioactivity LRL Site 300, January–June 1970

Sampling location	Number of samples	Alpha radioactivity[a] (fCi/m³)		Beta radioactivity[a] (fCi/m³)	
		Average	Maximum	Average	Maximum
1[b]	14	<0.2	<0.2	138	821
2	26	< .2	1.0	194	459
3	22	< .2	< .2	212	704
4	23	< .2	< .2	232	755
5	29	< .2	1.2	209	610
6	20	< .2	< .2	139	362
7	25	<1.0	<1.0	198	596
8	29	< .2	< .2	222	633
9	27	< .2	1.1	240	937
10	24	< .2	1.0	235	651
11	26	< .2	< .2	221	549
Summary	250	<0.2	1.2	208	937

[a] Limit of detection—alpha radioactivity—location 1–6, 8–11, 0.2 fCi/m³.
location 7, 1.0 fCi/m³.
beta radioactivity—location 1–6, 8–11, 3 fCi/m³.
location 7, 10 fCi/m³.
Variations in limits of detection result from differing flow rates. Estimated error limits—alpha radioactivity, ±20 percent
beta radioactivity, ±20 percent.

[b] Sampler inoperative for several weeks.

None of the average concentrations of air, water, and soil samples exceeded the standards of comparison applicable to activities at the test site, nor did any of the results increase significantly compared to 1969 data. Therefore, it appears that radiological control measures at Site 300 were adequate and that no significant radioactivity was released to the environment near the site during this period.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January—June 1969	April 1970
July—December 1969	November 1970

Reported Nuclear Detonations, April 1971

(Includes seismic signals presumably from foreign nuclear detonations)

No nuclear detonations were reported by the U.S. Atomic Energy Commission for April 1971.

The U.S. Atomic Energy Commission announced that the United States had recorded seismic signals, presumably from a Soviet underground nuclear explosion on April 24, 1971. The signals originated at approximately 10:33 EST, at the Semipalatinsk nuclear test area and were equivalent to those of an underground nuclear explosion in the yield range of 20–200 kilotons.

Information in this section is based on data received during the month, and is subject to change as additional information may become available. Persons requiring information for purposes of compiling announced nuclear detonation statistics are advised to contact the Division of Public Information, U.S. Atomic Energy Commission, Washington, D.C. 20545.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1971—[illegible]

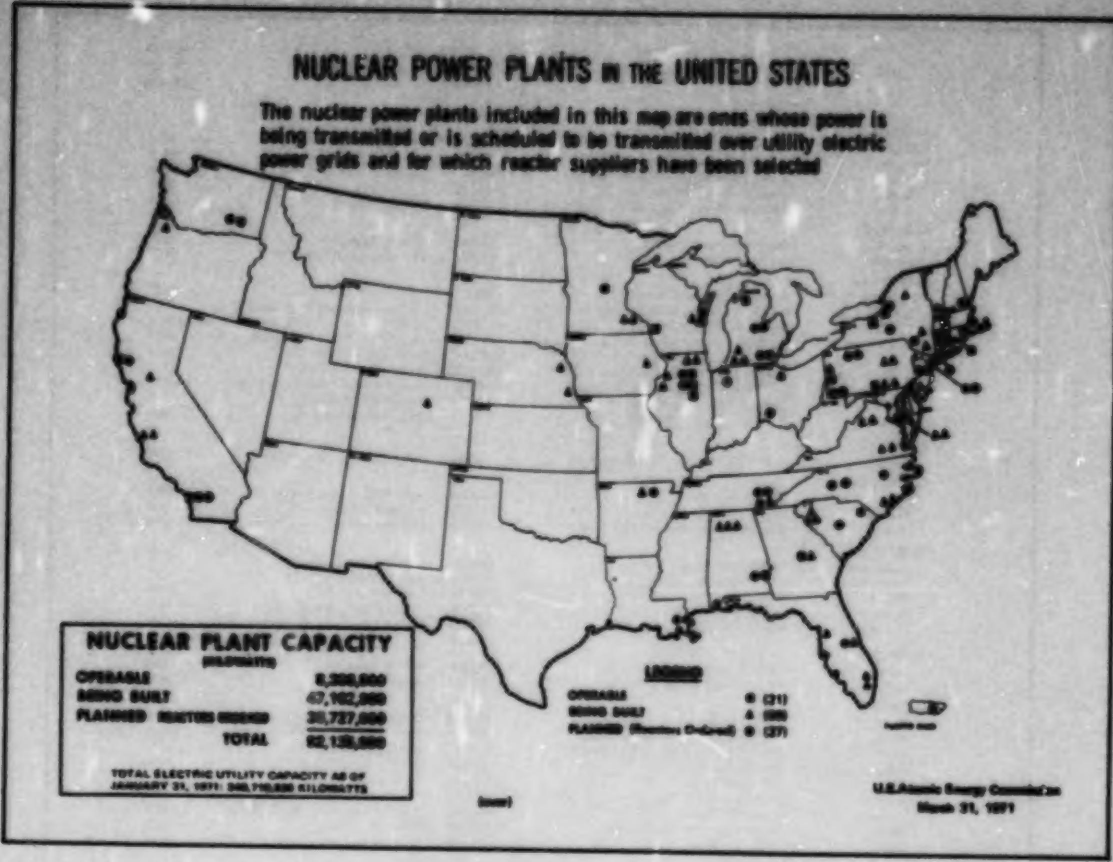
NUCLEAR POWER PLANTS IN THE UNITED STATES
The nuclear power plants included in this map are ones whose power is being transmitted or is scheduled to be transmitted over utility electric power grids and for which reactor suppliers have been selected
NUCLEAR PLANT CAPACITY
(KILOWATTS)
OPERABLE 8,309,000
BEING BUILT 47,102,800
PLANNED REACTORS ORDERED 36,727,000
TOTAL 92,138,800
TOTAL ELECTRIC UTILITY CAPACITY AS OF JANUARY 31, 1971: 340,710,830 KILOWATTS
LEGEND
OPERABLE ● (21)
BEING BUILT ▲ (55)
PLANNED (Reactors Ordered) ● (37)
(over)
U.S. Atomic Energy Commission
March 31, 1971

Figure 1. Nuclear power plants in the United States

SITE	PLANT NAME	CAPACITY (Net Kilowatts)	UTILITY	INITIAL DESIGN POWER
ALABAMA				
Decatur	Browns Ferry Nuclear Power Plant: Unit 1	1,065,000	Tennessee Valley Authority	1972
Decatur	Browns Ferry Nuclear Power Plant: Unit 2	1,065,000	Tennessee Valley Authority	1972
Decatur	Browns Ferry Nuclear Power Plant: Unit 3	1,065,000	Tennessee Valley Authority	1973
Dothan	Joseph M. Farley Nuclear Plant: Unit 1	829,000	Alabama Power Co.	1975
Dothan	Joseph M. Farley Nuclear Plant: Unit 2	829,000	Alabama Power Co.	1977
ARKANSAS				
London	Arkansas Nuclear One: Unit 1	820,000	Arkansas Power & Light Co.	1973
London	Arkansas Nuclear One: Unit 2	920,000	Arkansas Power & Light Co.	1975
CALIFORNIA				
Humboldt Bay	Humboldt Bay Power Plant: Unit 3	68,500	Pacific Gas & Electric Co.	1963
San Clemente	San Onofre Nuclear Generating Station: Unit 1	430,000	So. Calif. Ed. & San Diego Gas & El. Co.	1967
San Clemente	San Onofre Nuclear Generating Station: Unit 2	1,140,000	So. Calif. Ed. & San Diego Gas & El. Co.	1975
San Clemente	San Onofre Nuclear Generating Station: Unit 3	1,140,000	So. Calif. Ed. & San Diego Gas & El. Co.	1977
Diablo Canyon	Diablo Canyon Nuclear Power Plant: Unit 1	1,060,000	Pacific Gas & Electric Co.	1973
Diablo Canyon	Diablo Canyon Nuclear Power Plant: Unit 2	1,060,000	Pacific Gas & Electric Co.	1974
Clay Station	Rancho Seco Nuclear Generation Station	804,000	Sacramento Municipal Utility District	1972
Pt. Arena	Mendocino Power Plant: Unit 1	1,128,000	Pacific Gas & Electric Co.	1977
Pt. Arena	Mendocino Power Plant: Unit 2	1,128,000	Pacific Gas & Electric Co.	1979
COLORADO				
Platteville	Ft. St. Vrain Nuclear Generating Station	330,000	Public Service Co. of Colorado	1972
CONNECTICUT				
Haddam Neck	Haddam Neck Plant	575,000	Conn. Yankee Atomic Power Co.	1967
Waterford	Millstone Nuclear Power Station: Unit 1	652,100	Northeast Utilities	1971
Waterford	Millstone Nuclear Power Station: Unit 2	828,000	Northeast Utilities	1974
FLORIDA				
Turkey Point	Turkey Point Station: Unit 3	693,000	Florida Power & Light Co.	1971
Turkey Point	Turkey Point Station: Unit 4	693,000	Florida Power & Light Co.	1972
Red Level	Crystal River Plant: Unit 3	858,000	Florida Power Corp.	1972
Ft. Pierce	Hutchinson Island: Unit 1	800,000	Florida Power and Light Co.	1974
Ft. Pierce	Hutchinson Island: Unit 2	800,000	Florida Power and Light Co.	1976
GEORGIA				
Baxley	Edwin I. Hatch Nuclear Plant: Unit 1	786,000	Georgia Power Co.	1973
Baxley	Edwin I. Hatch Nuclear Plant: Unit 2	786,000	Georgia Power Co.	1976
ILLINOIS				
Morris	Dresden Nuclear Power Station: Unit 1	200,000	Commonwealth Edison Co.	1960
Morris	Dresden Nuclear Power Station: Unit 2	809,000	Commonwealth Edison Co.	1970
Morris	Dresden Nuclear Power Station: Unit 3	809,000	Commonwealth Edison Co.	1971
Zion	Zion Nuclear Plant: Unit 1	1,050,000	Commonwealth Edison Co.	1972
Zion	Zion Nuclear Plant: Unit 2	1,050,000	Commonwealth Edison Co.	1973
Cordova	Quad-Cities Station: Unit 1	809,000	Comm. Ed. Co.-Ia.-Ill. Gas & Elec. Co.	1971
Cordova	Quad-Cities Station: Unit 2	809,000	Comm. Ed. Co.-Ia.-Ill. Gas & Elec. Co.	1972
Seneca	LaSalle Co. Nuclear Station: Unit 1	1,078,000	Comm. Ed. Co.-Ia.	1975
Seneca	LaSalle Co. Nuclear Station: Unit 2	1,078,000	Comm. Ed. Co.-Ia.	1976
INDIANA				
Dune Acres	Bailly Generating Station	660,000	Northern Indiana Public Service Co.	1976
IOWA				
Cedar Rapids	Duane Arnold Energy Center: Unit 1	529,700	Iowa Electric Light and Power Co.	1973
LOUISIANA				
Taft	Waterford Generating Station: Unit 1	1,165,000	Louisiana Power & Light Co.	1976
MAINE				
Wiscasset	Maine Yankee Atomic Power Plant	790,000	Maine Yankee Atomic Power Co.	1972
MARYLAND				
Lusby	Calvert Cliffs Nuclear Power Plant: Unit 1	845,000	Baltimore Gas and Electric Co.	1973
Lusby	Calvert Cliffs Nuclear Power Plant: Unit 2	845,000	Baltimore Gas and Electric Co.	1974
MASSACHUSETTS				
Rowe	Yankee Nuclear Power Station	175,000	Yankee Atomic Electric Co.	1961
Plymouth	Pilgrim Station	655,000	Boston Edison Co.	1971
MICHIGAN				
Big Rock Point	Big Rock Point Nuclear Plant	70,300	Consumers Power Co.	1963
South Haven	Palisades Nuclear Power Station	700,000	Consumers Power Co.	1970
Lagoona Beach	Enrico Fermi Atomic Power Plant: Unit 1	60,900	Detroit Edison Co.	1970
Lagoona Beach	Enrico Fermi Atomic Power Plant: Unit 2	1,123,000	Detroit Edison Co.	1973
Bridgman	Donald C. Cook Plant: Unit 1	1,054,000	Indiana & Michigan Electric Co.	1973
Bridgman	Donald C. Cook Plant: Unit 2	1,060,000	Indiana & Michigan Electric Co.	1974
Midland	Midland Nuclear Power Plant: Unit 1	492,000	Consumers Power Co.	1976
Midland	Midland Nuclear Power Plant: Unit 2	818,000	Consumers Power Co.	1977
MINNESOTA				
Monticello	Monticello Nuclear Generating Plant	545,000	Northern States Power Co.	1971
Red Wing	Prairie Island Nuclear Generating Plant: Unit 1	530,000	Northern States Power Co.	1972
Red Wing	Prairie Island Nuclear Generating Plant: Unit 2	530,000	Northern States Power Co.	1974
*	–	1,201,000	Tennessee Valley Authority	1977
*	–	1,201,000	Tennessee Valley Authority	1978

* Site not selected.

Figure 1. Nuclear power plants in the United States—Continued

SITE	PLANT NAME	CAPACITY (Net Kilowatts)	UTILITY	INITIAL DESIGN POWER
NEBRASKA				
Fort Calhoun	Ft. Calhoun Station: Unit 1	457,400	Omaha Public Power District	1972
Brownville	Cooper Nuclear Station	778,000	Nebraska Public Power District and Iowa Power and Light Co.	1973
NEW JERSEY				
Toms River	Oyster Creek Nuclear Power Plant: Unit 1	560,000	Jersey Central Power & Light Co.	1969
Lacey Township	Forked River Generating Station: Unit 1	1,140,000	Jersey Central Power & Light Co.	1975
Salem	Salem Nuclear Generating Station: Unit 1	1,090,000	Public Service Electric and Gas, N. J.	1973
Salem	Salem Nuclear Generating Station: Unit 2	1,090,000	Public Service Electric and Gas, N. J.	1974
Newbold Island	Newbold Nuclear Generating Station: Unit 1	1,088,000	Public Service Electric and Gas, N. J.	1975
Newbold Island	Newbold Nuclear Generating Station: Unit 2	1,088,000	Public Service Electric and Gas, N. J.	1977
NEW YORK				
Indian Point	Indian Point Station: Unit 1	265,000	Consolidated Edison Co.	1963
Indian Point	Indian Point Station: Unit 2	873,000	Consolidated Edison Co.	1971
Indian Point	Indian Point Station: Unit 3	965,000	Consolidated Edison Co.	1973
Scriba	Nine Mile Point Nuclear Station	500,000	Niagara Mohawk Power Co.	1970
Rochester	R. E. Ginna Nuclear Power Plant: Unit 1	420,000	Rochester Gas & Electric Co.	1970
Brookhaven	Shoreham Nuclear Power Station	819,000	Long Island Lighting Co.	1975
Lansing	Bell Station	838,000	New York State Electric & Gas Co.	1978
Verplanck	Verplanck: Unit 1	1,115,000	Consolidated Edison Co.	1977
Scriba	James A. Fitzpatrick Nuclear Power Plant	821,000	Power Authority of State of N. Y.	1973
NORTH CAROLINA				
Southport	Brunswick Steam Electric Plant: Unit 1	821,000	Carolina Power and Light Co.	1976
Southport	Brunswick Steam Electric Plant: Unit 2	821,000	Carolina Power and Light Co.	1974
*		821,000	Carolina Power and Light Co.	–
Cowans Ford Dam	Wm. B. McGuire Nuclear Station: Unit 1	1,150,000	Duke Power Co.	1975
Cowans Ford Dam	Wm. B. McGuire Nuclear Station: Unit 2	1,150,000	Duke Power Co.	1976
OHIO				
Oak Harbor	Davis-Besse Nuclear Power Station	872,000	Toledo Edison-Cleveland Electric Illuminating Co.	1974
Moscow	Wm. H. Zimmer Nuclear Power Station: Unit 1	810,000	Cincinnati Gas & Electric Co.	1974
OREGON				
Rainier	Trojan Station	1,130,000	Portland General Electric Co.	1974
PENNSYLVANIA				
Peach Bottom	Peach Bottom Atomic Power Station: Unit 1	40,000	Philadelphia Electric Co.	1967
Peach Bottom	Peach Bottom Atomic Power Station: Unit 2	1,065,000	Philadelphia Electric Co.	1972
Peach Bottom	Peach Bottom Atomic Power Station: Unit 3	1,065,000	Philadelphia Electric Co.	1973
Pottstown	Limerick Generating Station: Unit 1	1,065,000	Philadelphia Electric Co.	1975
Pottstown	Limerick Generating Station: Unit 2	1,065,000	Philadelphia Electric Co.	1977
Shippingport	Shippingport Atomic Power Station: Unit 1	90,000	Duquesne Light Co.	1957
Shippingport	Beaver Valley Power Station: Unit 1	847,000	Duquesne Light Co.-Ohio Edison Co.	1973
Middletown	Three Mile Island Nuclear Station: Unit 1	819,000	Metropolitan Edison Co.	1972
Middletown	Three Mile Island Nuclear Station: Unit 2	831,000	Jersey Central Power & Light Co.	1974
Berwick	Susquehanna Steam Electric Station: Unit 1	1,052,000	Pennsylvania Power and Light	1977
Berwick	Susquehanna Steam Electric Station: Unit 2	1,052,000	Pennsylvania Power and Light	1979
SOUTH CAROLINA				
Hartsville	H. B. Robinson S. E. Plant: Unit 2	700,000	Carolina Power & Light Co.	1971
Seneca	Oconee Nuclear Station: Unit 1	841,000	Duke Power Co.	1971
Seneca	Oconee Nuclear Station: Unit 2	886,000	Duke Power Co.	1972
Seneca	Oconee Nuclear Station: Unit 3	886,000	Duke Power Co.	1973
Parr	–	900,000	South Carolina Electric & Gas Co.	1977
TENNESSEE				
Daisy	Sequoyah Nuclear Power Plant: Unit 1	1,124,000	Tennessee Valley Authority	1974
Daisy	Sequoyah Nuclear Power Plant: Unit 2	1,124,000	Tennessee Valley Authority	1974
Spring City	Watts Bar Nuclear Plant: Unit 1	1,170,000	Tennessee Valley Authority	1976
Spring City	Watts Bar Nuclear Plant: Unit 2	1,170,000	Tennessee Valley Authority	1977
VERMONT				
Vernon	Vermont Yankee Generating Station	513,900	Vermont Yankee Nuclear Power Corp.	1971
VIRGINIA				
Gravel Neck	Surry Power Station: Unit 1	780,000	Virginia Electric & Power Co.	1971
Gravel Neck	Surry Power Station: Unit 2	780,000	Virginia Electric & Power Co.	1972
Mineral	North Anna Power Station: Unit 1	845,000	Virginia Electric & Power Co.	1974
Mineral	North Anna Power Station: Unit 2	845,000	Virginia Electric & Power Co.	1975
WASHINGTON				
Richland	N-Reactor/WPPSS Steam	790,000	Washington Public Power Supply System	1966
Richland	Hanford No. 2	1,135,000	Washington Public Power Supply System	1977
WISCONSIN				
Genoa	LaCrosse Boiling Water Reactor	50,000	Dairyland Power Cooperative	1969
Two Creeks	Point Beach Nuclear Plant: Unit 1	497,000	Wisconsin Michigan Power Co.	1970
Two Creeks	Point Beach Nuclear Plant: Unit 2	497,000	Wisconsin Michigan Power Co.	1971
Carlton	Kewaunee Nuclear Power Plant: Unit 1	540,000	Wisconsin Public Service Co.	1972
PUERTO RICO				
Puerto De Jobos	Aguirre Nuclear Power Plant	583,000	Puerto Rico Water Resources Authority	1975

Figure 1. Nuclear power plants in the United States—Continued

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

ENVIRONMENTAL MONITORING AND DISPOSAL OF RADIOACTIVE WASTES FROM U.S. NAVAL NUCLEAR-POWERED SHIPS AND THEIR SUPPORT FACILITIES, 1970. *M. E. Miles, J. J. Mangeno, and R. D. Burke. Radiological Health Data and Reports*, Vol. *12*, May 1971, pp. 235–244.

This report summarizes data on disposal of radioactive wastes from U.S. Naval nuclear-powered ships and their support facilities and summarizes results of environmental monitoring performed to confirm adequacy of waste disposal limits and procedures. The total radioactivity discharged into all ports and harbors was 24 millicuries in 1970, less than one hundredth the total annual discharges of the early 1960's. Results of environmental surveys of harbor water and bottom sediment for gross radioactivity and for cobalt-60 show that (1) no increase in radioactivity above normal background levels has been detected in harbor water, (2) discharges of liquid wastes from U.S. Naval nuclear-powered ships have not caused a measurable increase in the general background radioactivity of the environment, and (3) low-level cobalt-60 radioactivity is detectable in localized areas of harbor bottom sediment around a few piers at operating bases and shipyards where maintenance and overhaul of Naval nuclear-powered ships have been conducted over a period of several years; these levels have decreased in recent years.

This report confirms that procedures used by the Navy to control discharges of radioactivity from U.S. Naval nuclear-powered ships and their support facilities have been effective in protecting the health and safety of the general public.

KEYWORDS: Discharges, disposal, harbors, monitoring, nuclear-powered ships, radioactivity, U.S. Navy, wastes.

RADIATION EXPOSURE TO A PHANTOM PATIENT DURING SIMULATED CHIROPRACTIC SPINAL RADIOGRAPHY. *J. I. Levine, J. W. Howe*, and *J. W. Rolofson. Radiological Health Data and Reports*, Vol. *12*, May 1971, pp. 245–251.

Radiographic exposures to various organs of a simulated patient were determined for 31 techniques of spinal radiography used by doctors of chiropractic. It was determined that the radiation exposure from the most commonly used techniques would be reduced by changing to techniques using higher filtration, higher kilovoltage with reduced milliampere-seconds, and smaller beam areas. The use of split or graduated screens, step wedges, and masks also reduced radiation exposure to the simulated patient without reducing the radiographic quality of the films.

KEYWORDS: Chiropractor, exposure, phantom, radiographic techniques, radiography, spine, x-ray.

RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 12, Number 6, June 1971

Radiological Health Data and Reports, a monthly publication of the Environmental Protection Agency, presents data and reports provided by Federal, State, and foreign governmental agencies, and other cooperating organizations. Pertinent original data and interpretive manuscripts are invited from investigators.

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels. This responsibility was delegated to the Bureau of Radiological Health, Public Health Service. Pursuant to the Reorganization Plan No. 3 of 1970, effective December 2, 1970, this responsibility was transferred to the Radiation Office of the Environmental Protection Agency which was established by this reorganization.

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ENVIRONMENTAL PROTECTION AGENCY
William D. Ruckelshaus, Administrator

Reports

Radioactive Waste Discharges to the Environment from a Nuclear Fuel Reprocessing Plant

Joe E. Logsdon and *John W. N. Hickey*[1]

The Nuclear Fuel Services fuel reprocessing plant has been in operation since 1966 and has provided valuable experience in waste management problems related to this type of facility. The large quantities of radioactivity which must be controlled at a nuclear fuel reprocessing plant virtually eliminate discharge-and-dilution as a satisfactory method of disposing of radionuclides which concentrate through environmental media. Radionuclides such as strontium-90, ruthenium-106, cesium-137, cesium-134, cobalt-60, tritium, and krypton-85 have been found in environmental media around NFS. These indicate that pathways to the public do exist as a result of operation of the facility. However, studies to date have indicated that typical population doses in the vicinity of NFS are not significantly different from doses received in other portions of the State.

On April 30, 1963, the Atomic Energy Commission (AEC) issued to Nuclear Fuel Services, Inc. (NFS), a permit for construction of the first commercial nuclear fuel reprocessing plant in the United States. Construction was completed in June 1965, at which time receipt and storage of spent reactor fuel began. The AEC granted a provisional operating license in April 1966, and operations began on April 20, 1966. Two other commercial reprocessing plants are under construction in Illinois and South Carolina, and others are being planned.

The function of a nuclear fuel reprocessing plant is to salvage reusable materials from spent reactor fuel. Nuclear reactor plants discharge to the environment a very small portion of the radioactivity generated by their operations. The remainder of the radioactivity is contained within the fuel cladding. A reprocessing plant chemically separates plutonium and unused uranium from the associated fission products in the spent fuel. The uranium can be reused as reactor fuel, and plutonium is stockpiled for possible future use as reactor fuel. The remaining waste materials include radioactive fission and activation products. Reprocessing operations include the disassembly of fuel bundles and the cutting and dissolution of fuel rods. Consequently, a large amount of potentially releasable radioactive material is involved, as opposed to reactor operations where radioactive fission products are contained within the fuel cladding.

The purpose of this report is to provide a general description of the NFS facility and information concerning the discharge of radioactive materials to the environment by the plant, and to relate these discharges to plant operations and discharge limits. As required by the AEC, Nuclear Fuel Services routinely prepares operating reports which include information concerning amounts of radioactive waste released to the environment. These reports are the principal source of data for this report.

Site description

The NFS reprocessing plant is located near the center of Western New York Nuclear Service Center (WNYNSC), in the township of Ashford, Cattaraugus County, New York. A map of the site is provided in figure 1. Western N.Y. Nuclear Service Center is a 3,331-acre, State-owned preserve, 30 miles southeast of Buffalo. It is completely

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[1] Mr. Logsdon is a health physicist with the Environmental Protection Agency, and Mr. Hickey is a student at Notre Dame and was a COSTEP with the U.S. Public Health Service, Bureau of Radiological Health, during the summer of 1970.

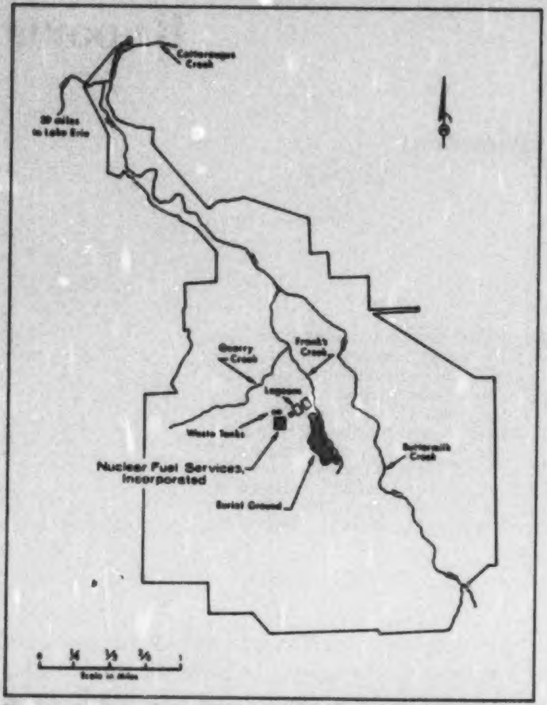

Figure 1. Site of the Western New York Nuclear Service Center

fenced and posted with "no trespassing" signs, and the NFS plant is 1,200 meters from the nearest site boundary. The NFS plant, lagoons, waste tanks, and burial grounds are enclosed inside a 10-foot-high chain-link and barbed-wire fence. The plant is equipped with a lagoon system for low-level, liquid-waste storage and discharge and a 200-foot stack for gaseous waste discharges. Wastes with high levels of radioactivity are stored in buried tanks on the site (see figure 1 for location).

The total population of the five counties in this area was 1,370,000 in 1960. Statistics on population within various radii of the plant and population density are provided in table 1. Dairying and farming are principal industries in the area.

Fuel reprocessing

The plant operation consists of separation and recovery of plutonium and unused uranium from spent fuel elements. NFS is capable of reprocessing 1 metric ton (tonne) per day of any low-enriched nuclear fuel which can be reduced to a nitric acid solution. The fuel is cooled at least 150 days before processing, and most fuel is cooled for over a year, thus permitting radioactive decay of the shorter-lived radionuclides.

Table 1. Population in vicinity of Nuclear Fuel Services (*1*)

Radius from site	Population within radius (1960)	Population density within radius (persons/sq. mi.)
5 miles	5,765	73
10 miles	15,644	50
15 miles	39,297	56
20 miles	62,432	50
25 miles	170,573	87

The spent fuel is transported to NFS in shielded casks by rail or truck. Each cask is placed in the unloading pool, a tank of water 44-feet deep. There the casks are opened, and the fuel elements are transferred into storage canisters. After an appropriate storage time, the canisters are moved to the processing area. An underwater conveyor carries the canisters from the storage pool to the shielded Process Mechanical Cell (PMC) where the reprocessing begins as diagrammed in figure 2. Each fuel element is removed from its canister, mechanically chopped into pieces, put into baskets, and stored in the General Purpose Cell (GPC) for later chemical processing. After analysis and adjustment, the feed from the chemical processing cell is jetted to the extraction cells (figure 2), where the fission products are chemically separated from the uranium and plutonium, and the uranium and plutonium are separated from each other. The uranium and plutonium solutions are then purified, evaporated to desirable concentrations, and packaged in geometrically safe containers for storage and shipment. The fission products in the waste solution are processed as high-level liquid waste. The fuel reprocessing operation for a particular batch usually takes 30–60 days and can involve up to 60 tonnes of spent fuel.

Technical specifications

NFS is required to operate its plant in accordance with an AEC license and associated technical specifications (*2*) which establish operating limi-

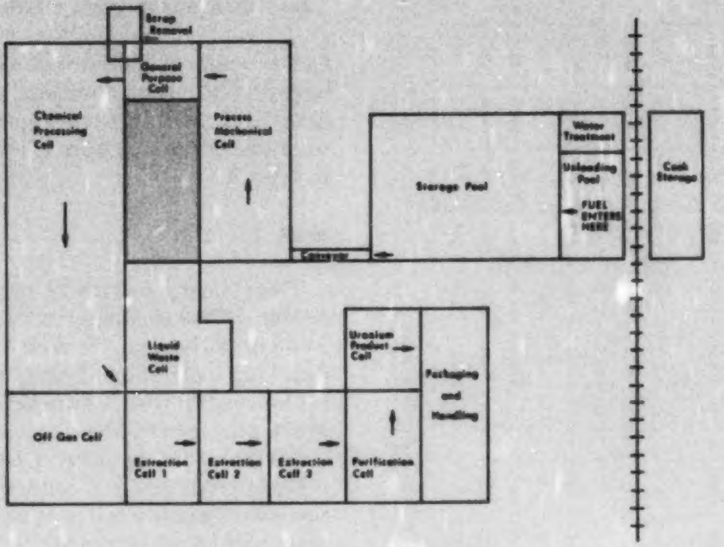
Scrap Removal
General Purpose Cell
Chemical Processing Cell
Process Mechanical Cell
Storage Pool
Water Treatment
Unloading Pool
FUEL ENTERS HERE
Cask Storage
Conveyor
Liquid Waste Cell
Uranium Product Cell
Packaging and Handling
Off Gas Cell
Extraction Cell 1
Extraction Cell 2
Extraction Cell 3
Purification Cell

Figure 2. NFS Purex Process diagram

tations. Following are the limits in these technical specifications for gaseous waste discharges:

Krypton-85	12.6 kilocuries per day
Iodine-131	3.3 curies per year
Particulate	0.1 microcurie per second (monthly average gross alpha plus beta)

Stack sampling and continuous monitoring of stack effluent are used to confirm compliance with release limits.

Concentrations in liquid discharges are limited as follows (*2*): "Activity released to Cattaraugus Creek from all sources on the site shall not at any time result in a concentration as measured at the monitoring station in Cattaraugus Creek which exceeds twice the concentration specified in Title 10 Code of Federal Regulations Part 20; provided, however, that in any 365-consecutive-day period, the average concentration of radioactivity in Cattaraugus Creek shall not exceed that specified in Title 10 Code of Federal Regulations Part 20."

"No more than 48 combined equivalent curies of alpha and beta activity other than tritium shall be transferred to the storage lagoons during any calendar quarter."

For purposes of these limits, the point of discharge is currently defined as the point where Cattaraugus Creek leaves the WNYNSC site (figure 1).

Table 2 includes data on liquid and gaseous wastes discharges as a percentage of limit. The percentages are not proportional to gross activity for liquid wastes because the concentration limit is a function of the radionuclide content. Also, the limit is expressed as a maximum concentration, and therefore, the percentage of limit depends on the flow rate of the creek, as well as gross beta-gamma activity discharged.

Radioactive waste

There are at least six ways radioactivity could be released from NFS to the environment:

1. Leakage during shipping and handling;
2. Egress of contaminated personnel or material;
3. Gaseous particulate waste discharged from the stack;
4. Low level radioactive liquid released from lagoons to Buttermilk Creek;
5. Leakage from high level liquid waste storage

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tanks to creek system; and
6. Leakage from solid waste burial grounds.

Safe procedures and adequate equipment controls have prevented environmental contamination from items 1, 2, and 5 above. General information on the radioactive waste from the plant is provided in table 2.

Table 2. General operational data for Nuclear Fuel Services[a]

Operational data	1966				1967				1968				1969				1970		
	1st qtr.	2nd qtr.	3rd qtr.	4th qtr.	1st qtr.	2nd qtr.	3rd qtr.	4th qtr.	1st qtr.	2nd qtr.	3rd qtr.	4th qtr.	1st qtr.	2nd qtr.	3rd qtr.	4th qtr.	1st qtr.	2nd qtr.	3rd qtr.
Fuel processed (tonnes)	—	52.5	46.6	15.5	1.98	27.6	39.7	51.8	36.8	45.1	51.6	3.2	28.6	37.4	23.4	21.5	13	7.6	14
High and low-level solid waste buried onsite (Ci/qtr)	—	5.9	629	111	120	5,000	13,400	850	620	450	540	1,120	2,160	13,200	2,400	1,965	.083	.067	.25
High-level liquid waste in storage tanks (megacuries of cesium-134 and -137)	—	—	—	—	—	—	—	4.1	3.5	3.6	4.3	3.9	4.0	7.1	6.3	6.6	6.9	8.5	13
Liquid waste discharged (α-β less H^3, Ci/qtr)	.012	.3	2.8	5.1	7.0	3.6	4.2	22.6	15.7	5.4	4.7	20.7	20.6	44.4	35.3	30.3	29.14	18.44	26.8
Liquid waste discharged as percent of limit[b]	—	—	—	—	16.5	15.8	21.0	11.4	9.2	5.2	12.2	12.6	18.9	12.6	40.1	30.0	19.0	8.2	21.2
Tritium discharged in liquid waste (Ci/qtr)	3.2	19.5	212	58	1,080	1,218	1,380	536	920	356	925	441	1,125	2,045	773	2,037	1,695	1,018	930
Gaseous waste discharged (^{85}Kr megacuries)	—	.002	.058	.020	.052	.076	.13	.006	.036	.035	—	—	—	—	—	—	—	—	—
Gaseous waste discharged as percent of limit	—	[c].17	[c]5.0	[c]2.5	[c]4.6	[c]6.6	[c]11.4	[c]5.7	[c]3.1	[c]3.0	[d]8.5	[d]11.0	[d]13.0	[d]44.0	[d]19.0	[d]10.0	[d]39.0	[d]44.0	[d]34.0
Particulates in gaseous waste (Ci/qtr)	—	.011	.080	.048	.053	.164	.241	.025	.452	.397	.135	.079	.094	.005	.0008	.017	.008	.073	.077
Particulate discharges from stack (percent of limit)	—	—	—	6.1	6.67	20.83	30.07	3.13	56.0	47.67	18.4	9.23	11.27	.43	.39	2.37	1.17	8.01	9.53

[a] Based on reference 3.
[b] Based on limits of 3×10^{-7} μCi/ml for strontium-90, 1×10^{-6} μCi/ml for other beta emitters except tritium, and 5×10^{-6} μCi/ml for alpha emitters.
[c] Based on limit of 1.26×10^{4} Ci/day, and the average of quarterly totals discharged.
[d] Maximum percent of daily limit, stated in footnote [c].
—, data not reported.

Stack discharges

The primary sources of contaminated gaseous wastes are the chopping and dissolution processes. The gas is then put through a chemical scrubber, dual high-efficiency filters, and iodine filters before mixing with ventilation air and discharge to the atmosphere. The stack is 200 feet high with a nominal discharge rate of 50,000 cubic feet per minute. Krypton-85 is considered to be the most significant gaseous waste radionuclide. Due to the short half-life of iodine-131 (8 days) and the relatively long storage time before processing, it is released in quantities less than 1 percent of the maximum permissible amount. A small amount of iodine-129 with a half life of 1.7×10^{7} years is released. Insufficient data are available to date to evaluate the significance of introducing a small amount of this long-lived isotope into the iodine pool of the biosphere. The EPA Radiation Office published a study entitled "Public Health Aspects of Iodine-129 from the Nuclear Power Industry" (4) which briefly discussed iodine-129 in the envirionment around NFS. This study concluded that there is an apparent local buildup of iodine-129 taking place around NFS. However, there was insufficient information relative to pathways to relate concentrations to dose.

Low-level liquid wastes

The primary source of liquid waste with a low level of radioactivity is the condensate from the series of evaporators which are used to concentrate high-level liquid waste and to recover the acid. Low-level waste is generally considered to have gross alpha-plus-beta activity between 3×10^{-7} and 5×10^{-3} μCi/ml. Low-level wastes may be further decontaminated by evaporation and condensation prior to storage in lagoons, which provide additional decontamination through settling. Liquids in the lagoons are discharged at a con-

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trolled rate into Frank's Creek, which flows through the site to Buttermilk Creek and then to Cattaraugus Creek, which flows into Lake Erie.

The effluent discharge rate of the plant is about 50,000 gallons per day. The lagoon network has two 22,000-gallon interceptors, a 300,000-gallon lagoon, and two 2.3 million-gallon lagoons. The average holdup period is about 1 month, and the maximum holdup capacity is 100 days.

Table 3 lists the principal radionuclides contributed to the environment via liquid discharges from NFS. The percent of limit column refers to limits for concentrations in water and does not consider the possibility of radionuclide concentration through environmental media. Strontium-90 and cesium-137 are the greatest contributors to population dose when all exposure pathways are considered (*5*).

Figure 3 includes plots of liquid waste discharges and fuel reprocessed as functions of time. This figure indicates a general increase in low-level liquid waste discharged, with a decrease in fuel processed. NFS attributes this increase to the processing of higher exposure reactor fuel in 1969 (*6*), but the Northeastern Radiological Health Laboratory suggests (*7*) that waste management policy is also a factor. NFS modified the waste management policy during the last quarter of 1970 to reduce significantly the discharge of gross beta-gamma radioactivity (excluding tritium). The modified policy included the evaluations of the contribution of individual sources of radioactive liquid being discharged to the low-level liquid holdup system and reduction or elimination of these sources wherever possible and the limiting of gross beta concentrations released to Cattaraugus Creek to 150 pCi/liter.[2]

High-level liquid waste

High-level radioactive liquid waste comes from the extraction processes. This waste is concentrated and stored underground on the site (figure 1) in steel tanks which are in saucers enclosed by concrete vaults. The tanks are monitored for leakage both inside and outside the concrete, so that there is little possibility of a leak of radioactivity to the environment from this source. Even in the unlikely event that a leak should develop, the highly impermeable soil would prevent the spread of contamination.

Table 3. Radionuclides contributed to the environment in liquid effluent from NFS[a]

Radionuclide	Quantity discharged May to October 1969 (curies)	Percent of 10CFR20[b] concentration limit in Cattaraugus Creek water	
		June 17, 1969	November 4, 1969
Tritium	1,700	1.1	0.10
Ruthenium-106	52	5.2	.75
Cesium-137	8.0	.008	.15
Cesium-134	2.0	<1	<1
Strontium-90	8.3	17	23
Cerium-144	.16	<1	<1
Promethium-147	.092	<1	<1
Zirconium-95	.0046	<1	<1
Cobalt-60	.20	<1	<1
Antimony-125	.59	<1	<1
Manganese-54	.0027	<1	<1
Plutonium	.0018	<1	<1
Uranium	.032	<1	<1
Gross alpha	.048		

[a] Reference 7.
[b] Code of Federal Regulations, Title 10, Part 20, Appendix B, table D.

Figure 3 includes a plot of cesium-134 plus cesium-137 in high-level liquid waste in storage as a function of time. It is noted that there is sometimes a net decrease in the amount of activity in storage from quarter to quarter, even though new waste is constantly being added to the tanks. This fluctuation is probably due to the difficulty in obtaining a representative sample of the wastes, coupled with variations in the total volume due to boiloff of water from the tank.[3]

Solid waste

Solid radioactive waste consists of discarded claddings, equipment, and other materials used in operations. It is buried on the site (figure 1) in impervious, silty till with good ion-exchange properties.

Environmental considerations

There are many farms and dairies in the area of NFS. Major crops are beans, corn, oats, and wheat. A few dairy herds have access to Cattaraugus Creek. The creek has been used on a few occasions in the past for irrigation. It is not a public water supply, but it is used for recreational

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[2] Personal communication to Mr. Robert N. Miller (NFS) from Mr. Marvin M. Mann (AEC) dated December 4, 1970.

[3] Personal communication to Mr. M. S. Terpilak of the EPA Radiation Office from Dr. E. D. North of Nuclear Fuel Services, dated March 12, 1971.

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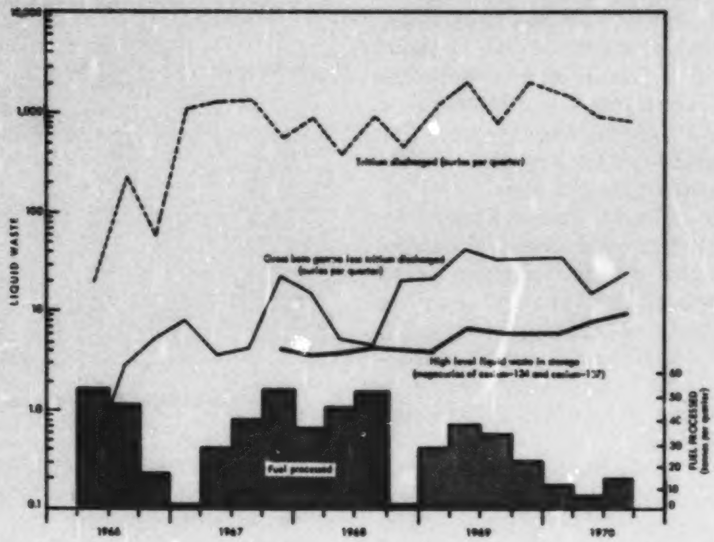

Figure 3. NFS liquid waste and amount of fuel processed

purposes, including fishing, swimming, picnicking, and boating. Thus, several potential indirect population exposure pathways exist in addition to direct exposure pathways through air, surface water, and external exposure.

There are programs of continuous monitoring at various locations around NFS. Measurements are taken on samples of water supplies, surface water, air, direct radiation, milk, silt, soil, vegetation, fish, and other wildlife. NFS is required by the AEC to continuously monitor gaseous and liquid waste discharges. A recent change (# 13) to the NFS technical specifications requires more environmental surveillance, including identification of exposure pathways. It also requires more detail in facility reports of waste discharges and environmental measurements than was previously required.

New York State conducts routine and special environmental monitoring around NFS (*8, 9*). The AEC is conducting a special independent program of measurements around NFS (*10*), which started in 1967 and has continued to the present. Table 4 provides a summary of the environmental surveillance being conducted around NFS. It includes type and number of samples, as well as types of analyses. The summary of the NFS environmental surveillance refers to the surveillance done prior to change # 13 to the technical specifications. This change requires the following environmental surveillance not previously included:

1. Direct radiation measurements at 3 locations along the site perimeter;
2. Tritium concentration in precipitation at 3 locations along the site perimeter;
3. Special milk samples to be analyzed for iodine-131 as a function of release quantity and meteorological conditions at the time of release;
4. Two semiannual milk samples to be analyzed for iodine-129, strontium-90, cesium-134, and cesium-137;
5. Fish samples during second and third quarter of each year to be analyzed for cesium-134, cesium-137, and strontium-90 in flesh plus strontium-90 in the skeleton with the median and geometric deviations of the measurements; and
6. An annual deer sample analyzed for cesium-134, cesium-137, and strontium-90 in the flesh and strontium-90 and strontium-89 in the skeleton.

Table 4. Summary of environmental surveillance programs around Nuclear Fuel Services[a]

	Media sampled									
	Air particulates	Direct radiation	Surface water	Surface water supplies	Silt	Fish	Milk	Vegetation	Soil	Deer
Nuclear Fuel Services:[a]										
Number of locations	4	—	6	1	1	1	1	1	1	—
Frequency	1 daily, 3 weekly	—	Monthly	Monthly	Monthly	Semi-annually	Weekly	Biweekly	Monthly	—
Type of analysis	Gross alpha, gross beta	—	Gross α, ^{131}I, gross β, ^{3}H, ^{90}Sr	Gross α, gross β, ^{90}Sr, ^{3}H	Gross α, ^{90}Sr, gross β	Gross α, ^{90}Sr, gross β	Gross β, ^{131}I	Gross α, ^{90}Sr, gross β	Gross α, ^{90}Sr, gross β	—
New York State:										
Number of locations	5	20	9	—	4	5	13	—	—	4 or 5
Frequency	Weekly	Annually	1 daily, 4 weekly, 4 monthly	—	Semi-annually	Semi-annually	1 farm/day	As necessary	As necessary	Semi-annually
Type of analysis	Gross β	γ	Gross β, ^{89}Sr, ^{90}Sr, γ ^{3}H, Pu.	—	γ, ^{90}Sr	γ, ^{90}Sr	γ, ^{3}H, ^{90}Sr, ^{131}I	—	—	γ, ^{90}Sr, ^{131}I, Pu in lung
Atomic Energy Commission:										
Number of locations	4	20	7	5	4	2	2	3	2	—
Frequency	Weekly	Monthly	Weekly	Monthly	Quarterly	Semi-annually	Monthly	Bimonthly	Bimonthly	Split samples with States
Type of analysis	Gross α, gross β, γ	Gross γ	Gross α, gross β, ^{90}Sr, ^{3}H, γ	Gross α, gross β, γ, ^{3}H, ^{90}Sr	Gross α, gross β, γ	Gross α, gross β, γ	Gross β, ^{131}I, ^{90}Sr, ^{137}Cs	Gross α, gross β-γ	Gross α, gross β-γ	—

[a] Does not reflect changes instituted as a result of change #13 to the NFS technical specifications.

The U.S. Public Health Service has conducted special environmental studies around NFS (*5, 7, 11*). These studies indicate that there are no immediate hazards to public health due to discharges from NFS, but they call attention to certain critical pathways of exposure to man which should be carefully monitored. The most important pathways for public exposure in the vicinity of the site appear to be through flesh from deer and flesh from fish in the area of NFS. The most significant radionuclides involved in these pathways are: strontium-90, cesium-137, cesium-134, and ruthenium-106. Krypton-85 and tritium may become important from the standpoint of worldwide buildup but not necessarily for local population exposure.

Conclusions

The Nuclear Fuel Services fuel reprocessing plant has been in operation since 1966 and has provided valuable experience in waste management problems related to this type of facility. The large quantities of radioactivity which must be controlled at a nuclear fuel reprocessing plant virtually eliminate discharge-and-dilution as a satisfactory method of disposing of radionuclides which concentrate through environmental media. Radionuclides such as strontium-90, ruthenium-106, cesium-137, cesium-134, cobalt-60, tritium, and krypton-85 have been found in environmental media around NFS. These indicate that pathways to the public do exist as a result of operation of the facility. However, studies to date have indicated that typical population doses in the vicinity of NFS are not significantly different from doses received in other portions of the State (*5*).

No particular time correlation exists between discharges of liquid waste from NFS and the amount of fuel reprocessed. This is to be expected due to the long holdup period in the lagoons and because quantities of radionuclides discharged depend primarily on the nature of the fuel processed and waste management practices. One might expect that, as experience is gained in waste processing techniques, the amount of radioactivity discharged relative to the amount of fuel processed would be lower. However, this has not been the case. Plots of the data indicate that this ratio actually has been increasing. Increased discharges and associated environmental measurements by New York State, PHS, and the AEC have led to increased surveillance around NFS.

NFS is presently installing additional equipment in order to reduce releases of radioactivity in low-level wastes. This equipment is designed to remove cesium and strontium from liquid wastes. These radionuclides are the greatest contributors to population dose from NFS discharges. The installation of this equipment is a step toward maintaining discharges as low as practical in keeping with recent amendments to Code of Federal Regulations, Title 10, Parts 20 and 50.

Acknowledgement

Appreciation is expressed to Mr. Thomas L. Robinson of the Division of Surveillance and Inspection for assistance in data compilation for this report.

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Characterization and Certification of Health Physics Technicians[1]

Ronald L. Kathren[2]

Personal, educational, and occupational history was obtained from a survey of more than 300 health physics technicians. The "average" technician is a 36-year-old married male with about 10 years of experience in the nuclear field. About two-thirds are veterans. Half of the group have completed two or more years of college, and most received specific training in radiological health on the job. Because of the diversity of educational and occupational backgrounds, a voluntary certification program is proposed, with certification requiring the passing of a written examination in addition to several years of experience and other requirements.

Among the newer members of the public health team are health physics technicians, a heterogeneous group concerned with protection against ionizing radiation. The composition of this group is the object of a study by a joint subcommittee of the Columbia Chapter and the Education and Training Committee of the Health Physics Society.[3] To date, this subcommittee has surveyed by mail questionnaire more than 300 nonprofessional personnel in the health physics–radiological health area, obtaining data on personal, educational, and occupational history.

The questionnaires were distributed through the 30 chapters of the Health Physics Society. This method of distribution, while almost certain to provide biases because of the characteristics of the membership of the chapters as well as the geographical distribution, nonetheless resulted in a very high percentage return (approximately 70 percent) of questionnaires and a sufficiently large sample (310 respondents) to permit some inferences to be drawn from the results. Returns were received from all over the United States with about an equal number from either side of the Mississippi River.

Although the questionnaire was designed to preserve the anonymity of the respondent and therefore did not provide the means of tying an individual to a specific job, it was nonetheless possible to get a qualitative feeling for the types of respondents. A significant fraction—perhaps on the order of 50 to 60 percent—were monitors associated with Atomic Energy Commission (AEC) laboratories or test sites. Employees of power reactors accounted for an estimated 5 to 10 percent of the total, and those employed by governmental agencies other than AEC (primarily Public Health Service (PHS)) probably accounted for a similar number. The remainder included those working in close support of the medical profession and employees of universities and industry in general. The distribution of respondents is probably similar to the actual distribution of technicians in the radiation protection field.

Personal and family history

As a group, health physics technicians are youthful males, having a median age of 37 and a mean age of 36, not too unexpected a finding when one considers the relative age of the nuclear industry and the demographic pattern of the past several decades. The age distribution has the positive skewness expected as the result of the minimum age at which employment is generally begun.

Nearly half of the respondents were born in the relatively sparsely populated areas of the so-called

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plains, Rocky Mountain, and, in part, southwestern States. Three of the States in this area—Idaho, Colorado, and New Mexico—alone contributed about 20 percent of the total, with Pennsylvania and New York contributing about 13 percent. Surprisingly, California, with its multiplicity of nuclear sites and proximity to the Nevada Test Site, was the birthplace of only about 3 percent of the respondents. Less than 1 percent were foreign-born. Ninety-four percent of the respondents were male, and 87 percent were married, with less than 4 percent, divorced or separated.

Family history data showed that the technicians typically came from a "white collar" family with 3.8 children, not appreciably different from the average U.S. family size for 1920–1950, when most were born (*1*). About 14 percent reported that their fathers were farmers, a number only slightly lower than the approximately 17 percent of the experienced labor force in farming pursuits in 1940 (*2*). (The year 1940 was used as a comparison year, since data are readily available (*3*) and the median health physics technician would have been 7 years old.) However, a relatively large proportion of the technicians' fathers were white-collar workers—31 percent as contrasted with 17 percent of the labor force in 1940. The proportions of professionals and skilled workers were comparable to those in the 1940 labor force, but the technicians reported only 7 percent of their fathers in unskilled or service occupations as compared with approximately 38 percent of the 1940 work force.

Approximately two-thirds of the respondents are serving or had served in the military, but only about one in three of these were veterans, indicating a reserve commitment and underscoring again the youthfulness of the group. When looking at the breakdown of individual services, as shown in table 1, there appears to be a somewhat greater proportion of Navy men than would be expected in a more random sample of occupational groups, and it may well be that many of the health physics technicians learned of the nuclear field through the very active Navy programs.

Educational background

The educational level of the 310 respondents is shown in figure 1. For comparison, the distribution of the father's educational level is also shown. Of significance is the high proportion of individuals with some formal college level work. The median educational level was 14 years (2 years of college).

In addition to the indicated categories of formal education, about two-fifths of the technicians had received additional formal education; nine had attended AEC-sponsored schools or courses; 28 had attended military schools; 31, technical schools; and 53 had taken miscellaneous college courses, PHS training courses, etc.

Table 1. Military background of health physics technicians

Branch of service	Percent
Army	26
Air Force	15
Navy	16
Marines	3
Other	2
No service	35
Rank in service	
Commissioned	14
Master Sgt., CPO, WO	14
Other enlisted	72

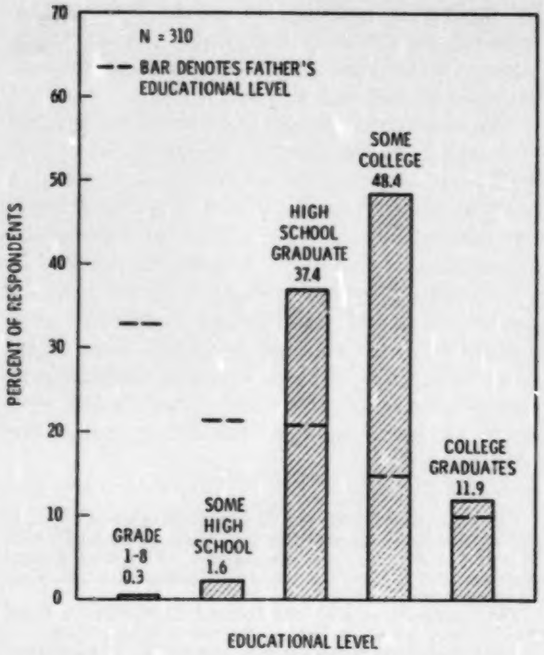

Figure 1. Educational levels of respondents

With respect to specific technician training, an overwhelming majority (75 percent) received their training on the job. Approximately equal numbers (12 percent) cited academic or a combination of academic and on-the-job training as their job preparation. Surprisingly, a similar fraction (75 percent thought their on-the-job training was adequate, even though it may have been only a few hours in duration and may have been their only orientation in radiological health. Only 18 percent—less than 1 in 5—felt that their preparation for their present jobs was inadequate.

Occupational history

The average respondent had nearly 11 years of experience in the nuclear field, and virtually all of that in the radiation protection area. However, the few with more than 20 years of experience tend to artificially inflate the mean. Examination of the distribution in figure 2 shows that most technicians—about two-thirds—have less than 10 years of experience. In part, this is a reflection of the youthfulness of the group, but since most of the technicians have been in the job market for 15 years or more, it indicates that, in general, they did not start in the nuclear field. In response to why they entered the nuclear field, 30 percent indicated interest; 14 percent, money; 11 percent, security; and most others gave reasons relating to interest, security, and future; statements like "a growing field" were not uncommon.

Generally, the health physics technician appears to be job stable. He has been on his present job an average of 5.9 years and has changed employers an average of 0.41 times. Fewer than 10 percent have changed employers more than twice since entering the nuclear field. Of those who have changed, pay was the overwhelmingly decisive factor, with layoffs and lack of opportunity for advancement in second place, far down the list. Salary was a factor in at least 48 of the 121 job changes.

Response to specific questions regarding job and employer revealed an interesting, mixed response, as summarized in table 2. In the main, the health physics technicians are an occupationally satisfied group, but one which does not think it is used to the full extent of its capabilities, nor paid adequately. Such a pattern could probably describe most professional groups in the scientific and technical disciplines.

Of especial interest and significance is how the respondents categorized themselves occupationally. About half felt that their jobs could be

Table 2. Job satisfaction factors of health physics technicians

Factor	Percent
Overall satisfaction	73
Promoted on job	54
Fully challenged	27
Adequate responsibility delegated	81
Advancement hampered by job class	56
Adequate pay	39
Acceptable location	59

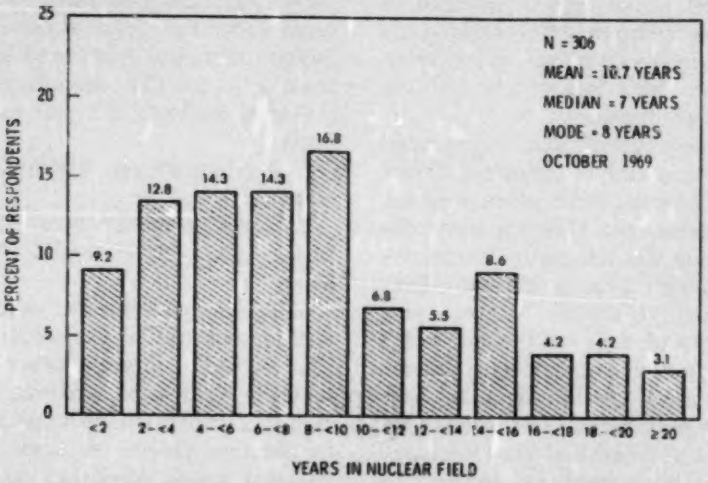

Figure 2. Health Physics technicians' experience in the field

described as "health physics technician," 35 percent as "nuclear technician," and 29 percent as "monitor." About 8 percent thought of themselves as "radiation technician," and a smattering of other responses were received. Several individuals listed more than one job title, indicative perhaps, of the multitude of titles used in industry to describe essentially the same job. A single job title would probably be beneficial, and would help with group identification. Health physics technician appears to be the most satisfactory title for, in addition to being the choice of the group itself, it identifies with a recognized and established professional group.

Certification

By a ratio of more than eight to one, the technicians felt that certification would be of benefit to them, and this alone may be adequate reason for instituting a certification program. However, there are other and perhaps more compelling reasons for a certification program. Perhaps the most obvious of these is the establishment of a baseline level of competence for a group that daily has responsibility for human life and well being and thousands of dollars worth of property. In this way, certification serves as a useful quality control device. One needs only to speculate on the consequences of an error directly attributable to incompetence: the release of curie quantities of radioactivity to the environment, overexposure that could be disabling or even fatal to a worker, a criticality accident with loss of life and tremendous economic ramifications.

Review of the educational and employment history of those participating in the survey underscores the need for a formal certification program. The fact that 82 percent felt their specific radiological health training was adequate, irrespective of duration coupled with three of four individuals receiving this training "on-the-job," places a very heavy reliance on the adequacy of the employer's training program. And since technicians are job stable and have relatively little intercourse with other technicians or professionals from other companies, the question of breadth of knowledge and scope may be raised. Such questions can easily be resolved by a sound certification program.

Certainly there is a precedent for certification of technicians, as exemplified by the certification programs for x-ray technicians and engineering technicians. In the case of both of these groups, uncertified persons can still work in the field, but certification is an important goal that has helped to upgrade both personnel and quality of work.

A sound certification program could be established along the lines of certification already available for other technician groups, such as x-ray technicians and engineering technicians. Logically, administration of the program should fall to the American Board of Health Physics, which could coordinate both the professional and technician certification programs. An independent or semi-independent subsidiary board, composed of both technicians and health physicists, could serve the program.

The basic requirements for certification as a health physics technician have already been proposed (*3*) and are reiterated below. These broad requirements appear reasonable and consistent with industrial and governmental job classifications and goals.

1. Course work beyond high school equivalent to no less than 60 semester hours of junior or technical college level course-work, with at least 36 semester hours in the sciences, engineering, and radiation technology;
2. A minimum of 2 years of experience in radiation monitoring or other health physics technician functions performed in a recognized program under the direct supervision of a certified health physicist. Additional experience can be substituted for the course work described in (1) above on the basis of 1 year for each 15 semester hours;
3. A minimum age of 21 years and good moral character;
4. Recommendation by a certified health physicist or two certified health physics technicians; and
5. Passing of a written examination, prepared and administered by the certifying board.

There would be no 'grandfather' clause; each would take the written examination to demonstrate his ability. Furthermore, it might be well to close the certification process to those employed as professional health physicists, and those to whom radiation protection work is secondary.

Beneficiaries of a certification program would be many. Potential employers would benefit from the preevaluation of prospective employees that such a certification program would accomplish. Knowledge that monitors, for example, have evidenced a minimum level of competence is both economically and psychologically reassuring. Management knows too well the price of incompetence.

The benefits of certification to the recipient are well known. Recognition for technical accomplishments, establishment of an identifiable group, and increased salary, job security, and status are but a few. The self-satisfaction that accompanies a meaningful certification provides a psychological lift and increased self-confidence.

The major benefactor, however, would be the public. Certification of health physics technicians is decidedly in the public interest if only as a quality control measure, but in addition provides a psychological service and has public relations value.

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Data

SECTION I. MILK AND FOOD

Milk Surveillance, February 1971

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption can be readily obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Office of Radiation Programs, Environmental Protection Agency, and the Office of Food Sanitation, Food and Drug Administration, U.S. Public Health Service, consists of 63 sampling stations; 61 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State Health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiological Health Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Environmental Protection Agency)—5 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations

The sampling locations that make up the networks presently reporting in *Radiological Health Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that are formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of meta-

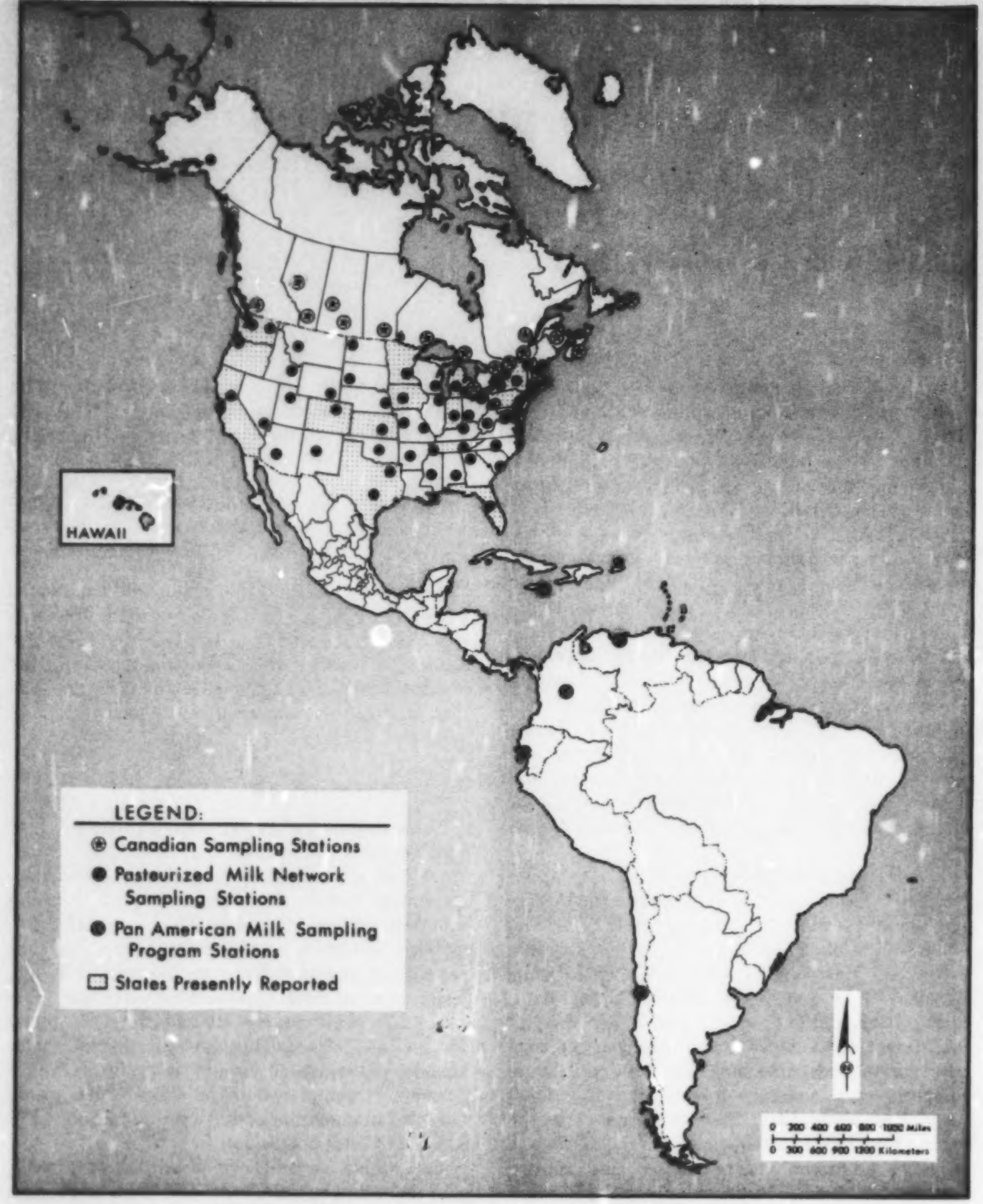
HAWAII
LEGEND:
⊛ Canadian Sampling Stations
● Pasteurized Milk Network Sampling Stations
● Pan American Milk Sampling Program Stations
▨ States Presently Reported
0 200 400 600 800 1000 Miles
0 300 600 900 1200 Kilometers

Figure 1. Milk sampling networks in the Western Hemisphere

bolically similar radionuclides (radiostrontium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variations, expressed in terms of 2-standard deviations (2σ), for these elements are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for May 1963–March 1966 (*3*), and were determined for use in general radiological health calculations or discussions.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Office of Radiation Programs conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested radiochemical laboratories. The generalized procedure for making such a study has been outlined previously (*4*).

The most recent study was conducted during May–July 1970, with 28 laboratories participating in an experiment on milk samples containing known concentrations of strontium-89, strontium-90, iodine-131, cesium-137, and barium-140 (*5*). Of the 18 laboratories producing data for the networks reporting in *Radiological Health Data and Reports*, 13 participated in the experiment.

The accuracy results of this experiment are shown in table 1. In general, considerable improvement is needed, especially in the accuracy measurements. These possible differences should be kept in mind when considering the integration of data from the various networks.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methods, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by

Table 1. Distribution of mean results, quality control experiment

Isotope and known concentration		Number of laboratories in each category			
		Acceptable[a]	Warning level[b]	Unacceptable[c]	Total
Strontium-89:	High (258 pCi/liter)	7 (44%)	1 (6%)	8 (50%)	16
	Low (15 pCi/liter)	11 (69%)	3 (19%)	2 (12%)	16
Strontium-90:	Intermediate (79.4 pCi/liter)	13 (57%)	4 (17%)	6 (26%)	23
	Low (32.0 pCi/liter)	5 (25%)	4 (20%)	11 (55%)	20
Iodine-131:	High (507 pCi/liter)	18 (67%)	2 (7%)	7 (26%)	27
	Low (49 pCi/liter)	16 (64%)	3 (12%)	6 (24%)	25
Cesium-137:	High (259 pCi/liter)	20 (74%)	3 (11%)	4 (15%)	27
	Low (53 pCi/liter)	17 (66%)	5 (19%)	4 (15%)	26
Barium-140:	High (302 pCi/liter)	18 (67%)	2 (7%)	7 (26%)	27
	Low (33 pCi/liter)	23 (92%)	0	2 (8%)	25

[a] Measured concentration equal to or within 2σ of the known concentration.
[b] Measured concentration outside 2σ and equal to or within 3σ of the known concentration.
[c] Measured concentration outside 3σ of the known concentration.

gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies. The methods used by each of the networks have been referenced in earlier reports appearing in *Radiological Health Data and Reports*.

A previous article (*6*) summarized the criteria used by the State networks in setting up their milk sampling activities and their sample collection procedures as determined during a 1965 survey. This reference and an earlier data article for the particular network of interest may be consulted should events require a more definitive analysis of milk production and milk consumption coverage afforded by a specific network.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. Many networks are analyzing composite samples on a quarterly basis for certain nuclides. The frequency of collection and analysis varies not only among the networks but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short periods of time and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and is generally increased at the first measurement or recognition of a new influx of this radionuclide.

The data in table 2 show whether raw or pasteurized milk was collected. An analysis (*7*) of raw and pasteurized milk samples collected during January 1964 to June 1966 indicated that, for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant (*7*). Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard-deviation counting errors or 2-standard-deviation total analytical errors from replicate analyses (*3*). The practical reporting level reflects analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below these practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical error or precision expressed as pCi/liter or percent in a given concentration range have also been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2-standard deviations)
Strontium-89	1–5 pCi/liter for levels <50 pCi/liter; 5–10% for levels ≥50 pCi/liter;
Strontium-90	1–2 pCi/liter for levels <20 pCi/liter; 4–10% for levels ≥20 pCi/liter;
Iodine-131 Cesium-137 Barium-140	4–10 pCi/liter for levels <100 pCi/liter; 4–10% for levels ≥100 pCi/liter.

For iodine-131, cesium-137, and barium-140, there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

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Federal Radiation Council guidance applicable to milk surveillance

In order to place the U.S. data on radioactivity in milk presented in *Radiological Health Data and Reports* in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions was presented in the December 1970 issue of *Radiological Health Data and Reports.*

Data reporting format

Table 2 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are routinely reported to *Radiological Health Data and Reports*. The relationship between the PMN stations and the State stations is shown in figure 2. The first column under each of the reported radionuclides gives the monthly average for the station and in parentheses, the number of samples analyzed in that month. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 2, surveillance results are given for strontium-90, iodine-131, and cesium-137 for February 1971 and the 12-month period, March 1970

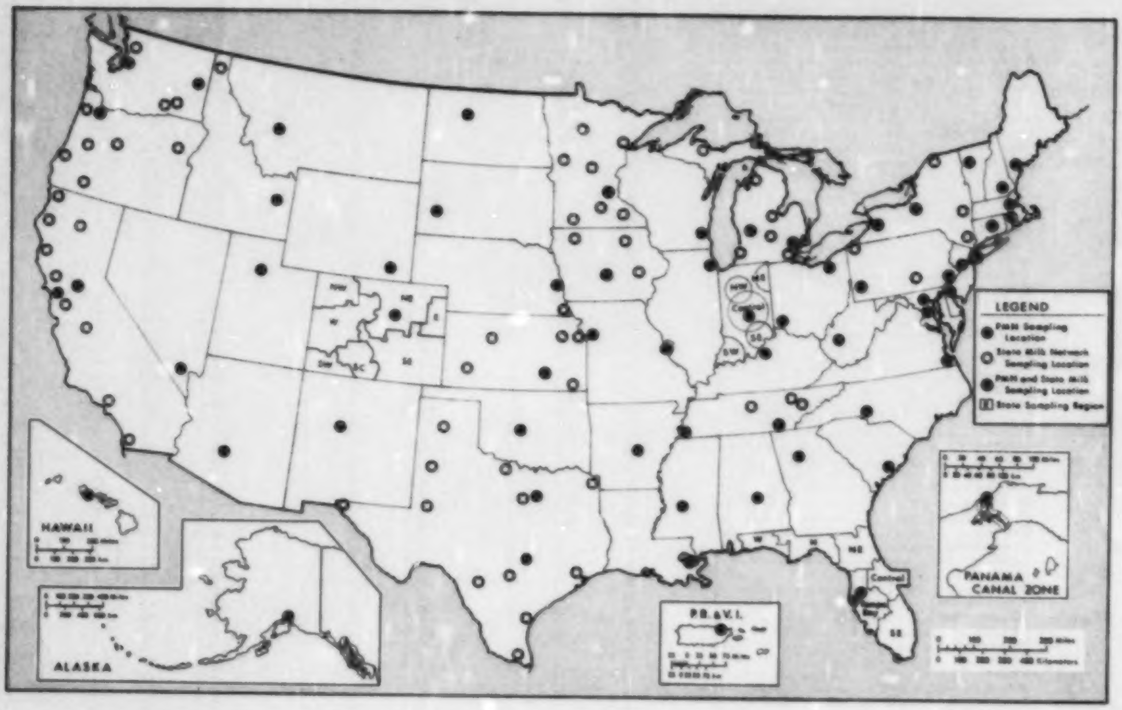

Figure 2. State and PMN milk sampling stations in the United States

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Table 2. Concentrations of radionuclides in milk for February 1971 and 12-month period, March 1970 through February 1971

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES:								
Ala:	Montgomery[c]	P	NA	6	0	0	16	9
Alaska:	Palmer[c]	P	NS	6	NS	0	NS	10
Ariz:	Phoenix[c]	P	NA	1	0	0	0	0
Ark:	Little Rock[c]	P	12	13	0	0	11	12
Calif:	Sacramento[c]	P	NA	2	0	0	0	0
	San Francisco[c]	P	NA	3	0	0	0	0
	Del Norte	P	12	17	0	0	7	13
	Fresno	P	6	2	0	0	0	1
	Humboldt	P	2	5	0	0	0	5
	Los Angeles	P	2	2	0	0	0	0
	Mendocino	P	3	3	0	0	0	2
	Sacramento	P	2	3	0	0	0	1
	San Diego	P	1	2	0	0	0	0
	Santa Clara	P	1	2	0	0	0	1
	Shasta	P	3	3	0	0	0	2
	Sonoma	P	4	3	0	0	0	1
Colo:	Denver[c]	P	NA	5	0	0	0	1
	West	R	(4)		0	1	0	4
	Northeast	R	(4)		0	0	0	0
	East	R	(4)		NS	0	NS	0
	Southeast	R	(4)		0	0	0	0
	South Central	R	(4)		NS		NS	
	Southwest	R	(4)		0	0	0	7
	Northwest	R	(4)		0	5	0	0
Conn:	Hartford[c]	P	NA	8	0	0	0	11
	Central	P	NS		NS		NS	
Del:	Wilmington[c]	P	NA	9	0	0	11	8
D.C:	Washington[c]	P	NA	7	0	0	13	7
Fla:	Tampa[c]	P	6	5	0	0	48	51
	West	R	12	9	0	0	12	16
	North	R	14	10	0	0	20	26
	Northeast	R	7	6	0	0	15	33
	Central	R	6	6	0	0	46	49
	Tampa Bay area	R	7	6	0	0	46	50
	Southeast	R	7	8	0	0	74	78
Ga:	Atlanta[c]	P	NA	11	0	0	17	14
Hawaii:	Honolulu[c]	P	0	2	0	0	0	0
Idaho:	Idaho Falls[c]	P	3	5	0	0	0	7
Ill:	Chicago[c]	P	6	7	0	0	13	10
Ind:	Indianapolis[c]	P	NA	8	0	0	13	7
	Northeast	P	8	9	0	5	10	10
	Southeast	P	8	10	0	0	10	12
	Central	P	10	11	0	0	15	12
	Southwest	P	9	11	0	0	10	12
	Northwest	P	10	12	0	0	15	10
Iowa:	Des Moines[c]	P	NA	7	0	0	0	3
	Iowa City	P	4	7	0 (2)	0	9 (2)	15
	Des Moines	P	5	8	0 (4)	0	13 (4)	10
	Spencer	P	3	5	0	0	0	8
	Fredericksburg	P	NS		NS		NS	
Kans:	Wichita[c]	P	NA	8	0	0	0	3
	Coffeyville	P	12	9	0	2	10	3
	Dodge City	P	7	7	0	2	0	1
	Falls City	R	NS	14	NS	3	NS	6
	Hays	P	14	13	0	2	12	2
	Kansas City	P	9	8	15	1	25	8
	Topeka	P	14	11	0	2	0	6
	Wichita	P	10	12	0	0	13	3
Ky:	Louisville[c]	P	NA	9	0	0	0	4
La:	New Orleans[c]	P	10	14	0	0	13	20
Maine:	Portland[c]	P	NA	10	0	0	17	21
Md:	Baltimore[c]	P	NA	8	0	0	0	7
Mass:	Boston[c]	P	8	10	0	0	16	21
Mich:	Detroit[c]	P	NA	8	0	0	13	10
	Grand Rapids[c]	P	NA	9	0	0	14	13
	Bay City	P	NA	7	<0	<0	16	11
	Charlevoix	P	9	12	<0 (2)	<1	15 (2)	15
	Detroit	P	NA	8	<0	<0	0	8
	Grand Rapids	P	9	9	<0	<0	13	8
	Lansing	P	8	9	<0 (2)	<0	14 (2)	14
	Marquette	P	10	13	<0 (2)	<0	20 (2)	23
	Monroe	P	6	6	<0 (2)	<0	6 (2)	3
	South Haven	R	8	8	<0 (4)	<0	4 (4)	6
Minn:	Minneapolis[c]	P	NA	10	0	0	11	11
	Bemidji	P	11	8	0	0	21	20
	Mankato	P	17	14	0	0	20	27
	Rochester	P	6	5	0	0	0	13
	Duluth	P	16	12	0	0	21	34
	Worthington	P	6	4	0	0	0	0
	Minneapolis	P	12	10	0	0	16	16
	Fergus Falls	P	8	6	0	0	13	12
	Little Falls	P	5	4	0	0	0	0

See footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for February 1971 and 12-month period, March 1970 through February 1971—Continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES: Continued								
Miss:	Jackson[c]	P	NA	12	0	0	0	10
Mo:	Kansas City[c]	P	NA	8	0	0	14	3
	St. Louis[c]	P	NA	8	0	0	0	4
Mont:	Helena[c]	P	NA	5	0	0	16	9
Nebr:	Omaha[c]	P	NA	5	0	0	0	1
Nev:	Las Vegas[c]	P	NA	3	0	0	0	0
N.H:	Manchester[c]	P	NA	9	0	0	18	20
N.J:	Trenton[c]	P	NA	7	0	0	0	10
N.Mex:	Albuquerque[c]	P	NA	3	0	0	0	0
N.Y:	Buffalo[c]	P	6	7	0	0	15	11
	New York City[c]	P	NA	10	0	0	12	17
	Syracuse[c]	P	NA	7	0	0	16	9
	Albany	P	8	7	0 (4)	0	26 (4)	[e]0
	Massena	P	5	7	0 (2)	0	30 (2)	25
	Newburg	P	17	8	0 (2)	0	[e]0 (2)	[e]0
	New York City	P	13	9	0	0	21	[e]0
	Syracuse	P	3	4	0 (2)	0	[e]0 (2)	[e]0
N.C:	Charlotte[c]	P	NA	11	0	0	0	12
N.Dak:	Minot[c]	P	NA	9	0	0	12	11
Ohio:	Cincinnati[c]	P	NA	7	0	0	0	4
	Cleveland[c]	P	NA	9	0	0	14	12
Okla:	Oklahoma City[c]	P	NA	7	0	0	11	6
Oreg:	Portland[c]	P	3	5	0	0	0	4
	Baker	P	NS	4	[e]0	[e]0	[e]0	6
	Coos Bay	P	NS	6	[e]0	[e]0	[e]0	13
	Eugene	P	NS	2	[e]0	[e]0	[e]0	1
	Medford	P	NS	3	[e]0	[e]0	[e]0	8
	Portland composite	P	NS	5	[e]0	[e]0	[e]0	6
	Portland local	P	NS	5	[e]0	[e]0	[e]0	6
	Redmond	P	NS	4	[e]0	[e]0	[e]0	[e]0
	Tillamook	R	NS	8	[e]0	[e]0	19	18
Pa:	Philadelphia[c]	P	NA	9	0	0	0	7
	Pittsburgh[c]	P	NA	11	0	0	18	15
	Dauphin	P	3	7	0	1	17	10
	Erie	P	3	10	0	1	24	24
	Philadelphia	P	13	8	0	0	24	15
	Pittsburgh	P	0	12	11	1	15	20
R.I:	Providence[c]	P	NA	9	0	0	16	17
S.C:	Charleston[c]	P	9	10	0	1	11	17
S.Dak:	Rapid City[c]	P	NA	7	0	0	0	4
Tenn:	Chattanooga[c]	P	NA	10	0	0	0	8
	Memphis[c]	P	NA	9	0	0	11	8
	Chattanooga	P	8	9	0	0	17	15
	Clinton	P	9	11	0	0	21	15
	Knoxville	P	6	7	0	0	15	13
	Nashville	P	6	6	0	0	13	10
	Fayetteville	P	9	11	0	0	11	14
Tex:	Austin[c]	P	NA	3	0	0	0	2
	Dallas[c]	P	NA	7	0	0	0	6
	Amarillo	R	NS	4	NA	NA	NS	5
	Corpus Christi	R	3	3	NA	NA	0	0
	El Paso	R	2	3	NA	NA	0	2
	Fort Worth	R	NS	5	NA	NA	NS	0
	Harlingen	R	NS	2	NA	NA	NS	0
	Houston	R	NS	6	NA	NA	NS	14
	Lubbock	R	2	3	NA	NA	0	0
	Midland	R	NS	2	NA	NA	NS	0
	San Antonio	R	NS	4	NA	NA	NS	0
	Texarkana	R	NS	8	NA	NA	NS	0
	Tyler	R	10	13	NA	NA	10	17
	Uvalde	R	NS	2	NA	NA	NS	0
	Wichita Falls	R	5	8	NA	NA	0	0
Utah:	Salt Lake City[c]	P	5	4	0	0	23	11
Vt:	Burlington[c]	P	NA	8	0	0	13	15
Va:	Norfolk[c]	P	NA	9	0	0	14	9
Wash:	Seattle[c]	P	NA	6	0	0	0	3
	Spokane[c]	P	NA	5	0	0	0	2
	Benton County	R	NS	0	NS	0	NS	2
	Franklin County	R	3	3	0	0	0	3
	Sandpoint, Idaho	R	8	11	0	0	12	22
	Skagit County	R	5	6	0	0	12	11
W.Va:	Charleston[c]	P	NA	8	0	0	0	5
Wisc:	Milwaukee[c]	P	NA	6	0	0	14	12
Wyo:	Laramie[c]	P	NA	5	0	0	0	1
CANADA:								
Alberta:	Calgary	P	(d)		(d)		29	18
	Edmonton	P	(d)		(d)		23	20
British Columbia:								
	Vancouver	P	(d)		(d)		16	24

See footnotes at end of table.

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Table 2. Concentrations of radionuclides in milk for February 1971 and 12-month period, March 1970 through February 1971—Continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
CANADA: Continued								
Manitoba:								
	Winnipeg	P	(d)		(d)		18	24
New Brunswick:								
	Fredericton	P	(d)		(d)		22	22
Newfoundland:								
	St. John's	P	(d)		(d)		18	34
Nova Scotia:								
	Halifax	P	(d)		(d)		8	22
Ontario:	Ft. William	P	(d)		(d)		15	18
	Ottawa	P	(d)		(d)		33	32
	Sault Ste. Marie	P	(d)		(d)		24	25
	Toronto	P	(d)		(d)		14	10
	Windsor	P	(d)		(d)		13	11
Quebec:	Montreal	P	(d)		(d)		23	18
	Quebec	P	(d)		(d)		30	28
Saskatchewan:								
	Regina	P	(d)		(d)		16	14
	Saskatoon	P	(d)		(d)		17	16
CENTRAL AND SOUTH AMERICA:								
Colombia:								
	Bogota	P	NS	0	NS	0	NS	0
Chile:	Santiago	P	0	0	0	0	0	0
Ecuador:	Guayaquil	P	NS	0	NS	0	NS	0
Jamaica:	Mandeville	P	NS	6	NS	0	NS	84
Venezuela:								
	Caracas	P	0	1	0	0	0	0
Canal Zone:								
	Cristobal[c]	P	NA	1	0	0	12	10
Puerto Rico:								
	San Juan[c]	P	NA	4	0	0	12	7
PMN average[f]			6	7	0	0	8	9

[a] P, pasteurized milk.
R, raw milk.

[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one anlaysis was made in a monthly period, the number of samples in the monthly average is given in parentheses.

[c] Pasteurized Milk Network station. All other sampling locations are part of the State or National network.

[d] Radionuclide analysis not routinely performed.

[e] The practical reporting levels for these networks differ from the general ones given in the text. Sampling results for the networks were equal to or less than the following practical reporting levels:

Iodine-131: Colorado—25 pCi/liter
Michigan—14 pCi/liter
Oregon—15 pCi/liter

Cesium-137: Colorado—25 pCi/liter
New York—20 pCi/liter
Oregon—15 pCi/liter

Strontium-90: New York—3 pCi/liter

[f] This entry gives the average radionuclide concentrations for the Pasteurized Milk Network stations denoted by footnote [c].
NA, no analysis.
NS, no sample collected.

through February 1971. Except where noted, the monthly average represents a single sample for the sampling station. Strontium-89 and barium-140 data have been omitted from table 2 since levels at the great majority of the stations for February 1971 were below the respective practical reporting levels. The following station average reflects a sample in which strontium-89 was detected: Idaho Falls, Idaho, (PMN), 6 pCi/liter; New Orleans, La., (PMN), 7 pCi/liter.

Iodine-131 results are included in the table, even though they were generally below practical reporting levels. Because of the lower guide levels established by the Federal Radiation Council, levels in milk for this radionuclide are of particular public health interest. In general, the practical reporting level for iodine-131 is numerically equal to the upper value of Range 1 (10 pCi/liter) of the FRC radiation protection guide.

Strontium-90 monthly averages ranged from 0 to 17 pCi/liter in the United States for the month of February 1971, and the highest 12-month average was 17 pCi/liter (Del Norte, Calif.) representing 8.5 percent of the Federal Radiation Council radiation protection guide. Cesium-137 monthly averages ranged from 0 to 74 pCi/liter in the United States for February 1971, and the highest 12-month average was 78 pCi/liter (Southeast Florida), representing 2.2 percent of the value derived from the recommendations given in the Federal Radiation Council report. Of particular interest are the consistently higher cesium-137 levels that have been observed in Florida (8) and Jamaica. Iodine-131 results for individual samples were all below the practical reporting level, with the exception of Kansas City, Kans., (State), 15 pCi/liter, and Pittsburgh, Pa., (State), 11 pCi/liter.

Acknowledgement

Appreciation is expressed to the personnel of the following agencies who provide data for their milk surveillance networks:

Bureau of Radiological Health
Division of Environmental Sanitation
California State Department of Health

Radiation Protection Division
Canadian Department of National Health
and Welfare

Radiological Health Section
Division of Occupational and Radiological Health
Colorado Department of Health

Radiological Health Services
Division of Medical Services
Connecticut State Department of Health

Radiological and Occupational Health Section
Department of Health and Rehabilitative Services
State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiation Control Section
Environmental Health Division
Kansas State Department of Health

Radiological Health Services
Division of Occupational Health
Michigan Department of Health

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Nuclear Engieeering
New York State Department of Environmental
Conservation

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Radiation Control Section
Division of Health
Washington Department of Social and Health
Service

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Radiostrontium in Milk, January-December 1969

Health and Safety Laboratory
U.S. Atomic Energy Commission

In 1954, the Health and Safety Laboratory began monitoring strontium-90 in liquid whole milk in New York to estimate the dietary contribution from ingestion of radiostrontium in milk. Subsequently, powdered milk monitoring was initiated at Perry, N.Y. (1954), and at Mandan, N. Dak. (1955). Liquid whole milk monitoring was started in Honolulu, Hawaii, in August 1959. Sampling was terminated at Mandan, N. Dak., and Honolulu, Hawaii, at the end of June 1965.

The New York City sample is a monthly composite of pasteurized milk purchased daily in quart containers at retail stores. Five large dairies are represented in the sample. The Perry samples are monthly composites of powdered whole milk for human consumption collected weekly in 5-pound lots from plants in the city. The strontium-90-to-calcium ratios in whole milk are presented in table 1.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–December 1968	October 1969

Table 1. Strontium-90 to calcium ratios in milk, January–December 1969[a]

Sampling location	Strontium-90 to calcium ratio (pCi ^{90}Sr/g Ca)											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
New York, N.Y. (liquid whole milk)	9.3	7.3	6.7	6.7	8.3	10.8	13.1	10.4	10.4	8.0	8.5	8.5
Perry, N.Y. (powdered whole milk)	8.0	7.4	7.2	6.2	6.4	6.4	8.8	8.6	9.4	7.2	7.2	7.9

[a] Data summarized from "Fallout Program Quarterly Summary Report," HASL-237, available from National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22151.

Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs reported in *Radiological Health Data and Reports* are as follows:

Program	Period reported	Issue
California Diet Study	January–June 1970	November 1970
Carbon-14 in Total Diet and Milk	July–December 1970	May 1971
Connecticut Standard Diet	July–December 1969	December 1970
Institutional Diet Samples	October–December 1970 and Annual Summary 1970	May 1971
Strontium-90 in Tri-City Diets	January–December 1969	June 1970

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SECTION II. WATER

The Environmental Protection Agency and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*), set the limits for approval of a drinking water supply containing radium-226 and strontium-90 at 3 pCi/liter and 10 pCi/liter, respectively. Higher concentrations may be acceptable if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities reported in *Radiological Health Data and Reports* are listed below.

Water sampling program	Period reported	Issue
California	July–December 1968	August 1970
Interstate Carrier Drinking Water	1967–1969	December 1970
Kansas	January–December 1969	September 1970
Minnesota	July–December 1969	May 1971
North Carolina	January–December 1967	May 1969
New York	January–December 1969	June 1970
Radiostrontium in Tap Water, *HASL*	January–December 1969	July 1970
Tritium in Community Water Supplies	1969	December 1970
Tritium Surveillance System	July–December 1970	May 1970
Washington	July 1968–June 1969	February 1971

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[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

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SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the Environmental Protection Agency, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports*.

Network	Period	Issue
Fallout in the United States and other Areas, *HASL*	July–December 1968 and January–December 1969	January 1971
Plutonium in Airborne Particulates and Precipitation	July–December 1970	June 1971
Surface Air Sampling Program, 80th Meridian Network, *HASL*	January–December 1968	April 1971

1. Radiation Alert Network
February 1971

Office of Air Programs
Environmental Protection Agency

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 70 locations distributed throughout the country (figure 1). Most of the stations are operated by State Health Department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate Environmental Protection Agency officials by mail or telephone depending on levels found. A compilation of the daily field estimates is available upon request from the Data Acquisition and Analysis Branch, Division of Air Quality and Emission Data, EPA, Cincinnati, Ohio. A detailed description of the sampling and analytical procedures was presented in the March 1968 issue of *Radiological Health Data and Reports*.

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique, during February 1971.

All field estimates reported were within normal limits for the reporting station.

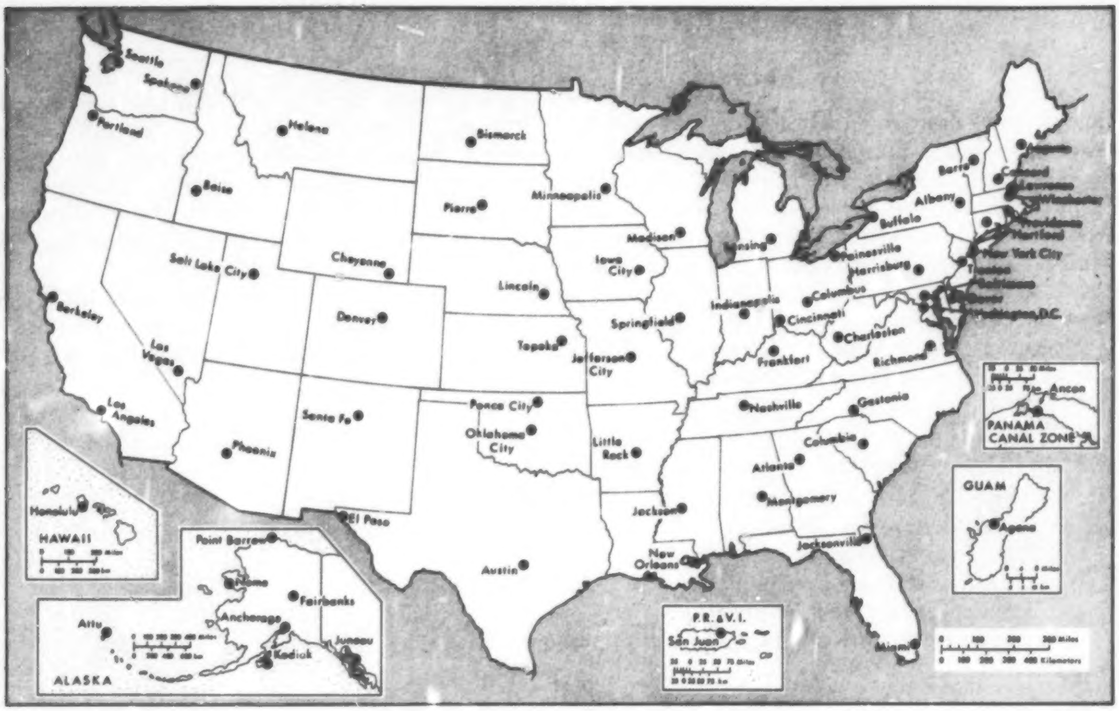
Seattle
Spokane
Portland
Helena
Bismarck
Boise
Pierre
Minneapolis
Salt Lake City
Cheyenne
Lincoln
Berkeley
Denver
Topeka
Las Vegas
Jefferson City
Los Angeles
Santa Fe
Ponca City
Oklahoma City
Phoenix
Honolulu
HAWAII
El Paso
Point Barrow
Nome
Fairbanks
Attu
Anchorage
Juneau
Kodiak
ALASKA
Austin
Madison
Lansing
Iowa City
Springfield
Indianapolis
Cincinnati
Columbus
Charleston
Frankfort
Richmond
Little Rock
Nashville
Gastonia
Columbia
Atlanta
Montgomery
Jackson
Jacksonville
New Orleans
Miami
Augusta
Barre
Concord
Lawrence
Winchester
Albany
Buffalo
Providence
Hartford
Painesville
Harrisburg
New York City
Trenton
Baltimore
Dover
Washington, D.C.
Ancon
PANAMA CANAL ZONE
GUAM
Agana
P.R. & V.I.
San Juan
0 100 200 300 Miles
0 100 200 300 400 Kilometers

Figure 1. Radiation Alert Network sampling stations

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Table 1. Gross beta radioactivity in surface air and precipitation, February 1971

Station location		Number of samples	Gross beta radioactivity (5-hour field estimate) (pCi/m³)			Number of samples	Precipitation			
							Total depth (mm)	Field estimate of deposition		
			Maximum	Minimum	Average[a]			Number of samples	Depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	19	6	0	1	4	130	4	130	43
Alaska:	Anchorage	2	0	0	0	0				
	Attu Island	27	1	0	0	0				
	Fairbanks	0				0				
	Juneau	10	15	2	6	9	163	7	140	0
	Kodiak	15	0	0	0	0				
	Nome	0				0				
	Point Barrow	0				0				
Ariz:	Phoenix	10	4	1	2	0				
Ark:	Little Rock	3	1	0	0	0				
Calif:	Berkeley	17	2	0	0	2	10	2	10	1
	Los Angeles	18	3	0	1	0				
C.Z:	Ancon	0				0				
Colo:	Denver	17	9	0	2	2	8	(b)		
Conn:	Hartford	18	0	0	0	9	86	9	86	2
Del:	Dover	17	0	0	0	0				
D.C:	Washington	24	1	0	0	0				
Fla:	Jacksonville	19	2	0	1	3	50	3	50	10
	Miami	14	0	0	0	3	25	2	23	0
Ga:	Atlanta	16	2	1	1	0				
Guam:	Agana	0				0				
Hawaii:	Honolulu	23	1	0	0	3	57	(b)		
Idaho:	Boise	17	3	0	1	3	18	3	18	0
Ill:	Springfield	7	1	0	1	0				
Ind:	Indianapolis	15	1	0	0	0				
Iowa:	Iowa City	17	0	0	0	5	74	5	74	0
Kans:	Topeka	19	2	0	0	4	16	4	16	1
Ky:	Frankfort	3	0	0	0	0				
La:	New Orleans	15	1	0	0	6	87	(b)		
Maine:	Augusta	2	0	0	0	1	16	1	16	0
Md:	Baltimore	17	1	0	0	8	66	8	66	0
Mass:	Lawrence	19	0	0	0	3	61	3	61	0
	Winchester	18	0	0	0	7	71	7	71	0
Mich:	Lansing	19	0	0	0	0				
Minn:	Minneapolis	19	0	0	0	3	15	3	15	2
Miss:	Jackson	13	1	0	0	3	96	3	96	0
Mo:	Jefferson City	19	3	0	1	4	50	4	50	0
Mont:	Helena	17	1	0	0	2	10	2	10	0
Nebr:	Lincoln	19	9	0	1	2	55	2	55	2
Nev:	Las Vegas	15	3	0	2	0				
N.H:	Concord	0				0				
N.J:	Trenton	18	1	0	0	7	100	7	100	4
N.Mex:	Santa Fe	18	1	0	1	0				
N.Y:	Albany	0				0				
	Buffalo	17	0	0	0	0				
	New York City	0				0				
N.C:	Gastonia	14	6	0	3	1	4	(b)		
N.Dak:	Bismarck	18	1	0	0	3	10	3	10	1
Ohio:	Cincinnati	0				0				
	Columbus	0				0				
	Painesville	20	1	0	0	11	68	11	68	30
Okla:	Oklahoma City	0				0				
	Ponca City	18	6	0	1	5	18	5	18	2
Oreg:	Portland	17	1	0	0	12	106	10	96	5
Pa:	Harrisburg	10	0	0	0	0				
P.R:	San Juan	0				0				
R.I:	Providence	17	1	0	0	0				
S.C:	Columbia	18	5	0	1	4	106	4	106	9
S.Dak:	Pierre	18	1	0	1	0				
Tenn:	Nashville	19	1	0	0	5	104	5	104	4
Tex:	Austin	5	2	1	2	0				
	El Paso	0				0				
Utah:	Salt Lake City	26	2	0	1	5	26	5	26	3
Vt:	Barre	9	0	0	0	3	62	3	62	7
Va:	Richmond	10	1	0	0	6	99	9	99	76
Wash:	Seattle	9	0	0	0	7	66	(b)		
	Spokane	13	1	0	1	0				
W.Va:	Charleston	17	1	0	[illegible]	9	79	9	79	73
Wisc:	Madison	19	1	0	0	6	84	6	84	12
Wyo:	Cheyenne	18	7	0	1	2	8	2	8	2
Network summary		898	15	0	1	172	69	5	60	9

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.
[b] This station is part of the plutonium in precipitation network. No gross beta measurements are done.

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2. Canadian Air and Precipitation Monitoring Program[1], February 1971

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 2), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports*.

Surface air and precipitation data for January 1971 are presented in table 2.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, February 1971

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	4	0.2	0.1	0.1	60	0.60
Coral Harbour	4	.1	.1	.1	21	.52
Edmonton	4	.1	.1	.1	23	.47
Ft. Churchill	4	.1	.0	.1	37	.76
Fredericton	4	.1	.1	.1	26	3.56
Goose Bay	4	.1	.0	.1	22	.87
Halifax	4	.2	.1	.1	69	.60
Inuvik	4	.1	.1	.1	30	.42
Montreal	4	.1	.0	.1	24	3.06
Moosonee	4	.1	.1	.1	37	1.13
Ottawa	4	.1	.1	.1	31	5.65
Quebec	4	.1	.1	.1	15	2.06
Regina	4	.1	.1	.1	57	.26
Resolute	5	.1	.0	.1	NS	NS
St. John's, Nfld	4	.1	.0	.1	23	1.75
Saskatoon	4	.1	.0	.1	83	.53
Sault Ste. Marie	3	.1	.0	.1	36	3.26
Thunder Bay	4	.1	.1	.1	79	5.01
Toronto	3	.1	.0	.1	69	7.27
Vancouver	4	.1	.0	.1	37	9.41
Whitehorse	4	.1	.0	.1	34	.06
Windsor	4	.1	.0	.1	44	4.06
Winnipeg	4	.1	.1	.1	161	.82
Yellowknife	3	.1	.1	.1	22	.21
Network summary	94	0.2	0.0	0.1	47	2.38

NS, no sample.

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[1] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

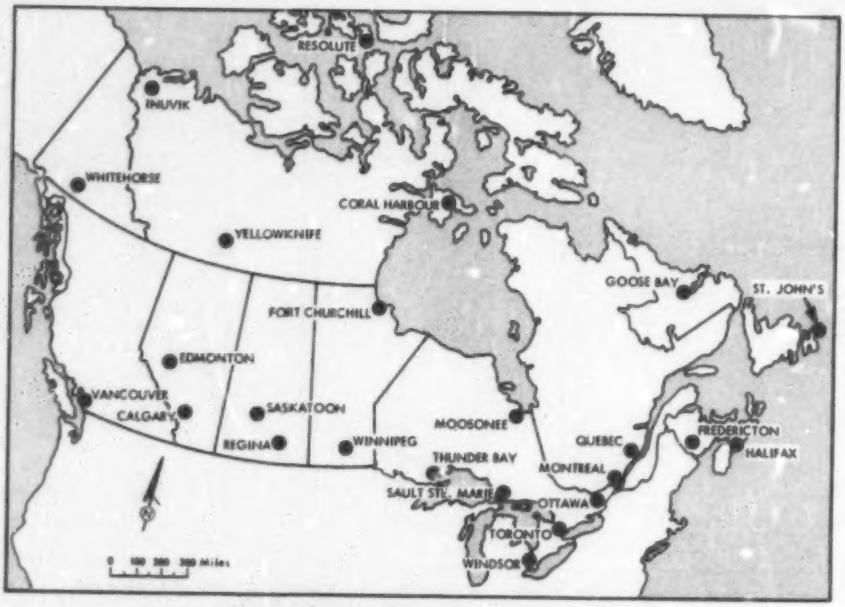
RESOLUTE
INUVIK
WHITEHORSE
CORAL HARBOUR
YELLOWKNIFE
GOOSE BAY
ST. JOHN'S
FORT CHURCHILL
EDMONTON
VANCOUVER
CALGARY
SASKATOON
REGINA
WINNIPEG
MOOSONEE
QUEBEC
FREDERICTON
HALIFAX
THUNDER BAY
MONTREAL
SAULT STE. MARIE
OTTAWA
TORONTO
WINDSOR
0 100 200 300 Miles

Figure 2. Canadian air and precipitation sampling stations

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3. Pan American Air Sampling Program February 1971

Pan American Health Organization and *Environmental Protection Agency*

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the Environmental Protection Agency (EPA) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 3. Analytical techniques were described in the March 1968 issue of *Radiological Health Data and Reports*. The February 1971 air monitoring results from the participating countries are given in table 3.

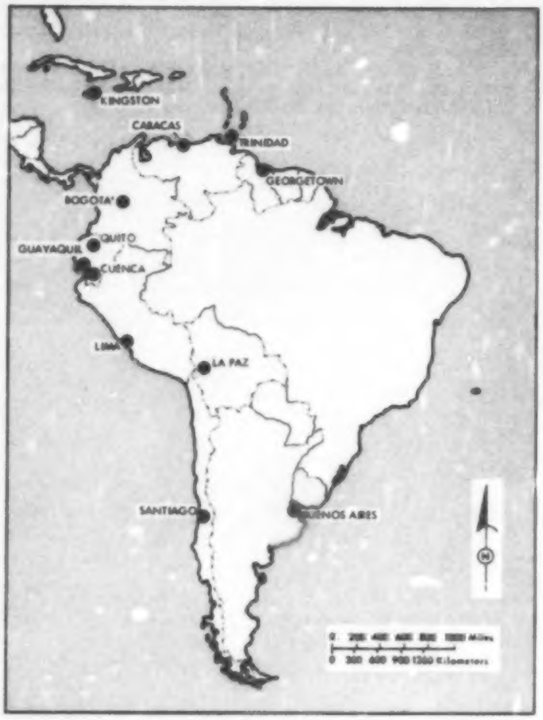

Figure 3. Pan American Air Sampling Program stations

Table 3. Summary of gross beta radioactivity in Pan American surface air, February 1971

Station location	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average[a]
Argentina: Buenos Aires	NS			
Bolivia: La Paz	17	0.04	0.00	0.02
Chile: Santiago	8	.20	.07	.18
Colombia: Bogota	18	.11	.02	.05
Ecuador: Cuenca	NS			
Guayaquil	NS			
Quito	NS			
Guyana: Georgetown	3	.29	.27	.28
Jamaica: Kingston	NS			NS
Peru: Lima	20	.19	.06	.11
Venezuela: Caracas	NS			
West Indies: Trinidad	13	.29	.04	.16
Pan American summary	79	0.30	0.00	0.10

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.

NS, no sample.

4. Plutonium in Airborne Particulates July–December 1970

Office of Radiation Programs and *Office of Air Programs, Environmental Protection Agency*

The Radiation Alert Network (RAN) of the Office of Air Programs, Environmental Protection Agency, routinely collects airborne particulate samples from 11 selected RAN stations for plutonium analyses. The plutonium analyses were initiated in November 1965, and references to the previous results through December 1969 have been published (*6*).

One-half of each individual air filter from the selected stations is sent to the Northeastern Radiological Health Laboratory, Winchester, Mass. The laboratory analyzes a composite of these samples for each station on a quarterly basis. The results for July–December 1970 are presented in table 4. The minimum detectable activities are 0.020 pCi and 0.015 pCi per sample for plutonium-238 and plutonium-239, respectively. The volume of air samples varies, generally ranging from 20,000 to 30,000 cubic meters per month.

In July 1970, the Rockville, Md., RAN station was discontinued. Plutonium analyses for the Maryland area are now performed on the air filters from the Baltimore, Md., RAN station.

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Table 4. Plutonium in airborne particulates, July–December 1970

Collection date (1970)	Anchorage	Phoenix	Denver	Honolulu	New Orleans	Baltimore	Buffalo	Gastonia	Pierre	Austin	Seattle
Plutonium-238: (aCi/m^3)											
July–September	[a] ND	6	6	4	5	4	6	6	4	6	4
October–December	NS	3	4	ND	2	ND	2	3	2	NS	2
Plutonium-239: (aCi/m^3)											
July–September	17	70	91	42	45	61	79	62	74	73	49
October–December	NS	40	33	15	25	22	23	30	23	NS	24
$^{239}Pu/^{238}Pu$:											
July–September	—	11.7	15.2	10.6	9.0	15.2	13.2	10.3	18.5	12.2	12.3
October–December	—	13.3	8.3	—	12.5	—	11.5	10.0	11.5	—	12.0

[a] Composite for July and August only.
ND, nondetectable.
NS, no sample.

Other coverage in *Radiological Health Data and Reports:*

Period	Issue
January–June 1970	March 1971

REFERENCES

(*1*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Study Program, CNHW–RP–3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(*2*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW–RP–4. Department of National Health and Welfare, Ottawa, Canada (December 1961).

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SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance, and environmental monitoring around nuclear facilities.

Strontium-90 in Human Bone, July-September 1970

Office of Radiation Programs
Environmental Protection Agency

To obtain data on the concentration of strontium-90 in man by age and geographical region, the Public Health Service began collecting human bone specimens in late 1961. Analyses of selected samples of people in older-age groups have shown their bone strontium-90 content to be low and age independent (*1*). Consequently, the target population includes children and young adults up to 25 years of age.

Although a few samples come from living persons as a result of surgical procedures, the majority are obtained post mortem. In the latter case, the specimens are limited to accident victims or persons who have died of an acute disease process that was not likely to impair bone metabolism. For analytical purposes, a sample of at least 100 grams of wet bone is desired. Generally, this amount is readily available from older children, but it presents some difficulties from the standpoint of infants and children under 5 years of age. Most specimens received to date have been vertebrae and ribs.

Laboratory procedures

The bones are analyzed at the Northeastern Radiological Health Laboratory of the Bureau of Radiological Health, at Winchester, Mass. Sample collection and preparation are explained elsewhere (*2*). Strontium-90 is measured by tributyl phos-

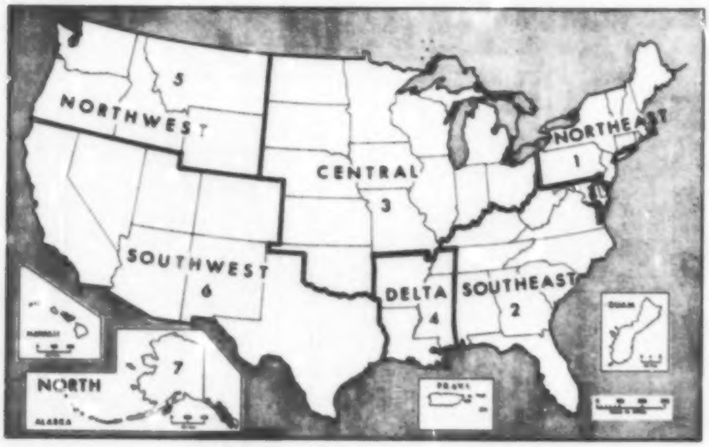

Figure 1. Geographical regions for human bone sampling

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[1] Period during which death or surgical procedure occurred.

Table 1. Strontium-90 in human bone, July–September 1970

Bone region and State	Bone type[a]	Age[b] (years)	Sex	Strontium-90 concentration[c] (pCi/kg bone)	Calcium concentration (g/kg bone)	^{90}Sr/Ca (pCi/g)
Northeast:						
Massachusetts	V	0	F	91.9 ± 12.5	30.6	3.00
New York	V, R	0	F	36.3 ± 5.9	19.7	1.84
	V, R	0	F	60.9 ± 5.4	30.3	2.01
	V, R, I	0	M	89.8 ± 8.2	31.3	2.87
Massachusetts	V	0	M	28.9 ± 6.0	32.8	.88
New York	V, R, I	0	M	47.2 ± 5.3	36.2	1.30
	V, R, I	0	F	37.6 ± 6.2	25.7	1.46
New Jersey	V, R	0	F	54.3 ± 7.8	40.9	1.33
New York	V	1	M	58.7 ± 9.8	25.1	2.34
	V, R, I	1	F	82.0 ± 7.6	31.5	2.60
Maine	V	2	M	82.3 ± 7.9	28.4	2.90
Massachusetts	V	2	M	82.3 ± 9.3	28.4	2.90
Connecticut	V	4	F	52.3 ± 7.0	31.0	1.69
Massachusetts	V	5	F	64.7 ± 8.7	27.2	2.38
	V	5	F	94.6 ± 9.2	26.2	3.61
New York	V	5	F	75.7 ± 11.5	33.1	2.29
	V	6	M	115.5 ± 9.2	38.0	2.97
	V	7	F	65.7 ± 10.2	31.0	2.12
New Jersey	B, S	9	M	38.5 ± 6.2	18.8	2.04
New York	V	9	M	68.7 ± 10.8	36.8	1.86
	V	10	M	38.2 ± 5.8	26.0	1.47
Massachusetts	V	11	M	62.6 ± 6.9	30.5	2.06
New York	V	14	F	63.6 ± 9.5	34.9	1.82
	V	16	M	87.6 ± 10.6	55.4	1.58
New Jersey	V, S	16	M	110.1 ± 11.3	39.7	2.78
New York	V	17	M	62.4 ± 7.6	31.4	1.98
Massachusetts	V	18	F	108.2 ± 10.3	40.1	2.10
	V	19	M	189.5 ± 18.6	51.3	3.70
Vermont	V	20	M	115.0 ± 9.7	40.1	2.87
New Jersey	S	20	M	50.1 ± 6.8	32.6	1.54
New York	V	24	M	60.4 ± 7.4	32.3	1.87
Pennsylvania	V	25	M	65.3 ± 9.2	30.0	2.18
Southeast:						
South Carolina	V	4	F	96.9 ± 10.7	27.8	3.49
	V	4	F	85.9 ± 8.7	30.3	2.84
	V	5	M	63.9 ± 7.6	30.7	2.08
North Carolina	V	5	F	113.1 ± 10.3	25.6	4.42
Maryland	V	7	F	101.6 ± 10.5	40.0	2.54
Virginia	V	9	F	74.4 ± 9.8	36.3	2.05
South Carolina	V	11	F	140.4 ± 13.7	43.7	3.21
Maryland	V	11	F	94.8 ± 12.8	48.7	1.95
North Carolina	V	14	F	165.8 ± 11.7	38.8	4.28
Tennessee	V	15	F	49.2 ± 6.7	43.9	1.12
North Carolina	V	15	F	105.3 ± 10.1	49.4	2.13
Maryland	V	15	M	89.1 ± 8.8	47.5	1.88
	V	16	M	93.2 ± 11.8	46.0	2.03
South Carolina	V	17	M	134.2 ± 11.5	47.7	2.81
	V	17	M	184.4 ± 12.1	45.8	4.02
North Carolina	V	18	M	109.2 ± 9.9	43.7	2.50
Tennessee	V	18	M	94.5 ± 10.5	51.8	1.82
North Carolina	V	21	M	114.1 ± 10.[illegible]	49.9	2.29
	V	22	F	107.7 ± 13.3	44.7	2.41
Virginia	V	22	F	111.4 ± 10.3	47.2	2.36
Maryland	V	22	F	106.0 ± 11.0	59.7	1.78
South Carolina	V	22	M	64.0 ± 7.9	44.0	1.45
Maryland	V	23	M	145.6 ± 12.6	70.7	2.06
	V	23	M	111.8 ± 10.9	48.1	2.32
	V	25	F	111.2 ± 11.5	51.6	2.15
	V	25	F	79.3 ± 10.5	59.5	1.33
	V	25	F	120.6 ± 12.2	50.3	2.40
Central:						
Ohio	V	0	M	72.0 ± 11.5	34.2	2.10
	V	0	F	68.2 ± 5.8	23.3	2.93
Wisconsin	V	2	M	71.3 ± 9.0	28.7	2.49
	V	3	F	5.3 ± 6.3	28.3	.19
	V	4	F	52.5 ± 10.0	63.4	.83
Ohio	V	6	F	62.9 ± 9.9	29.0	2.17
	V	6	M	101.5 ± 12.2	34.9	2.91
Michigan	V	6	F	57.9 ± 8.2	29.7	1.95
Wisconsin	V	7	M	54.8 ± 6.5	32.8	1.67
Michigan	V, R	7	F	225.3 ± 19.1	61.6	3.66
Ohio	V	9	M	41.9 ± 6.9	24.9	1.68
Wisconsin	V	10	F	75.7 ± 8.2	31.9	2.37
Minnesota	V	11	M	58.3 ± 6.7	38.0	1.54
Wisconsin	V	11	F	92.4 ± 8.8	51.7	1.79
Ohio	V	13	M	109.5 ± 9.8	54.5	2.01
	V	13	M	143.3 ± 12.1	51.3	2.80
	V	13	M	94.5 ± 13.4	50.9	1.86
Minnesota	V	14	M	54.8 ± 7.1	37.7	1.45
Ohio	V	14	M	320.9 ± 19.5	52.2	6.15
	V	15	F	88.2 ± 11.6	45.8	1.93
Minnesota	V	16	F	69.6 ± 6.8	42.9	1.62

See footnotes at end of table.

Table 1. Strontium-90 in human bone, July–September 1970

Bone region and State	Bone type[a]	Age[b] (years)	Sex	Strontium-90 concentration[c] (pCi/kg bone)	Calcium concentration (g/kg bone)	^{90}Sr/Ca (pCi/g)
Central (Continued)						
Ohio	V	16	F	182.6 ± 16.4	50.9	3.58
	V	18	M	95.4 ± 11.0	56.5	1.69
	V	19	M	147.0 ± 12.8	71.8	2.05
	V	19	M	103.1 ± 12.0	57.6	1.79
	V	19	M	106.0 ± 9.5	58.7	1.81
	V	19	F	136.2 ± 13.0	47.9	2.84
South Dakota	V	19	M	67.7 ± 7.5	40.7	1.66
Michigan	V	19	M	107.7 ± 12.9	64.5	1.67
Ohio	V	20	F	86.2 ± 12.2	59.1	1.46
	V	20	M	86.6 ± 7.6	46.0	1.88
	V	22	M	68.6 ± 7.1	46.0	1.49
	V	22	M	83.6 ± 10.1	52.4	1.60
Michigan	V	22	F	39.5 ± 6.9	45.1	.88
Ohio	V	22	M	80.2 ± 9.1	66.9	1.20
	V	23	M	99.9 ± 12.5	50.5	1.98
	V	23	F	84.0 ± 9.3	49.1	1.71
	V	23	F	58.4 ± 8.0	50.6	1.15
Kansas	V	24	M	79.6 ± 10.4	54.6	1.46
Ohio	V	24	F	69.9 ± 7.3	46.7	1.50
	V	25	M	120.2 ± 11.3	62.6	1.92
	V	25	M	86.5 ± 8.5	47.9	1.81
Delta:						
Louisiana	V	2	F	62.7 ± 10.1	27.7	2.26
	V	6	F	132.1 ± 12.0	35.7	3.70
	V	9	M	41.3 ± 8.1	27.1	1.52
	V	18	M	160.6 ± 17.6	57.7	2.78
Northwest:						
Oregon	V	4	M	82.5 ± 10.0	34.9	2.36
Southwest:						
Texas	V	10	M	37.3 ± 7.3	29.1	1.28
	V	16	M	59.9 ± 7.4	29.0	2.07
	V	20	F	60.2 ± 11.1	54.5	1.10

[a] Type of bone, V, vertebrae; R, rib; S, sternum; I, Ilium.
[b] Age given as of last birthday prior to death.
[c] Two-sigma counting error.

phate extraction of its yttrium daughter, which is precipitated as an oxalate. The strontium-90 content is then calculated (*3*) from the yttrium-90 activity. For the purpose of maintaining analytical reproducibility, "blind" duplicate analyses are performed on 10 to 20 percent of the samples.

The analytical results for strontium-90 in individual bones from persons dying during the third quarter (July–September) of 1970 are presented in table 1 in order of increasing age within each geographical region. These regions are indicated in figure 1. Reported values are given in picocuries of strontium-90 per kilogram of bone (as a rough indication of dose) and per gram of calcium (for comparison with other data and for purposes of model development). Two-sigma counting errors are reported for the bone concentration.

Following the pattern of earlier reports, subsequent articles will continue to provide interpretation of the data at appropriate stages in the program (*2–6*).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–March 1970	January 1971
April–June 1970	April 1971

REFERENCES

(*1*) RIVERA, J. Strontium-90 in human vertebrae, 1962–1963. Radiol Health Data 5:511–513 (October 1964).

(*2*) WEISS, E. S., W. H. LAND, K. H. FALTER, and R. M. HALLISEY. Strontium-90 content of human bones, 1961–1963. Radiol Health Data 5:231–239 (May 1964).

(*3*) PUBLIC HEALTH SERVICE, NORTHEASTERN RADIOLOGICAL HEALTH LABORATORY. Analysis of environmental samples, chemical and radiochemical procedures, NERHL 64–1. Northeastern Radiological Health Laboratory, Winchester, Mass. (April 1964).

(*4*) GAFFNEY, G. W., R. M. HALLISEY, M. S. MILLER, and A. S. GOLDIN. Strontium-90 in human bone, 1962–1963. Radiol Health Data 5:620–628 (December 1964).

(*5*) HALLISEY, R. M. and M. A. WALL. Strontium-90 in human bone, 1964–1965. Radiol Health Data Rep 8:415–419 (August 1967).

(*6*) BARATTA, E. J., E. S. FERRI, and M. A. WALL. Strontium-90 in human bones in the United States, 1962–1966. Radiol Health Data Rep 11:183–186 (April 1970).

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1]

Summaries of the environmental radioactivity data follow for the Atomics International and Hanford Atomic Products Operation.

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[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Atomics International[2]
July–December 1970

North American Rockwell Corporation
Canoga Park, Calif.

Atomics International, a division of North American Rockwell Corporation, has engaged in atomic energy research and development since 1946. The company designs, develops, and constructs nuclear reactors for central station and compact power plants, and for medical, industrial, and scientific applications.

The company headquarters is located in Canoga Park, Calif., approximately 23 miles northwest of downtown Los Angeles. The 290-acre Nuclear Development Field Laboratory (Santa Susana Facility), equipped with extensive testing facilities for the support of advanced nuclear studies, is located in the Simi Hills of Ventura County, approximately 29 miles northwest of downtown Los Angeles. The location of the above sites in relation to nearby communities is shown in figure 1.

The basic concept of radiological hazard control at Atomics International requires adequate containment of radioactive materials and, through rigid operational controls, minimizes effluent releases and external radiation levels. The environmental monitoring program provides a measure of the effectiveness of the company's radiological

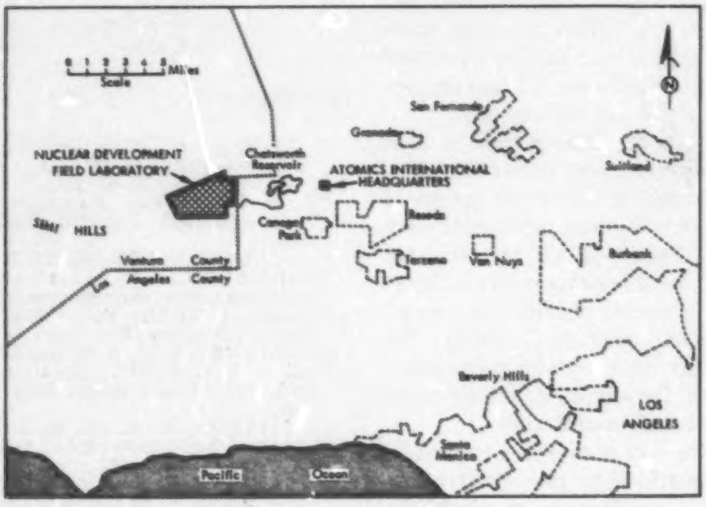
0 1 2 3 4 5 Miles
Scale
N
San Fernando
Granada
Sunland
NUCLEAR DEVELOPMENT FIELD LABORATORY
Chatsworth Reservoir
ATOMICS INTERNATIONAL HEADQUARTERS
Simi HILLS
Canoga Park
Reseda
Tarzana
Van Nuys
Burbank
Ventura County
Los Angeles County
Beverly Hills
LOS ANGELES
Santa Monica
Pacific Ocean

Figure 1. Atomics International facilities and vicinity

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[2] Summarized from "Environmental Monitoring, Semiannual Report, July 1 to December 31, 1970," Atomics International, Division of North American Rockwell Corporation.

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safety procedures and of engineering safeguards incorporated into facility designs.

The onsite environs of Atomics International headquarters and Nuclear Development Field Laboratory (NDFL) are surveyed monthly to determine the concentration of radioactivity in typical surface soil, vegetation, and water samples. The offsite environs are sampled monthly, except for soil and vegetation which are sampled quarterly. In addition, continuous environmental air monitoring at the sites provides information concerning long-lived airborne particulate radioactivity.

Counting and calibration procedures

Beginning in July 1970, radioactivity determinations for all environmental soil, vegetation, water, and air samples are performed with a low-background proportional counting system capable of simultaneous counting of both alpha and net beta radioactivity. The system permits the use of larger samples, thereby increasing the overall sensitivity to low radioactivity concentrations. The sample-detector configuration provides a nearly 2π geometry. The thin-window detector is continually purged with methane counting gas. A preset time mode of operation is used for all samples; however, an overriding preset count mode is available to limit the counting time for high activity samples.

The minimum detection limits shown in table 1 pertain only to the low-background counting system used during the last half of 1970. They were determined by using typical values for counting time, system efficiency, background count rates (approximately 0.05 cpm alpha and 1.0 cpm beta-gamma), and sample size. In addition, the minimum statistically significant amount of radioactivity, irrespective of sample configuration, is established as that amount equal in count rate to three times the standard deviation of the system background count rate.

Counting system efficiencies are determined routinely with RaD + E + F (with alpha absorber), thorium-230, and uranium-235 standard sources, and with potassium-40 in the form of standard reagent grade KCl, which is used to simulate soil and vegetation samples. Self-absorption standards are made by dividing sieved KCl into samples increasing in mass by 200-milligram increments from 100 to 3,000 milligrams. The samples are placed in copper planchets of the type used f environmental samples and counted. The ratio of disintegration rate to the observed net count rate for each sample is plotted as a function of sample weight (figure 2). The correction factor (ratio) corresponding to the environmental sample weight is obtained from the graph. The product of the correction factor and the net environmental sample count rate yields the sample activity (dpm). This method has been checked successfully by applying it to aliquots of uniformly mixed environmental samples of various weights and observing that the resultant specific activities fall within the expected statistical counting error.

Table 1. Minimum radioactivity detection limits

Sample	Radioactivity	Minimum detection limits (standard error)
Soil	Alpha	0.05 ± 0.03 (pCi/g)
	Beta-gamma	.22 ± .11 (pCi/g)
Vegetation	Alpha	.10 ± .06 (pCi/g-ash)
	Beta-gamma	.35 ± .18 (pCi/g-ash)
Water	Alpha	.20 ± .12 (pCi/liter)
	Beta-gamma	.63 ± .32 (pCi/liter)

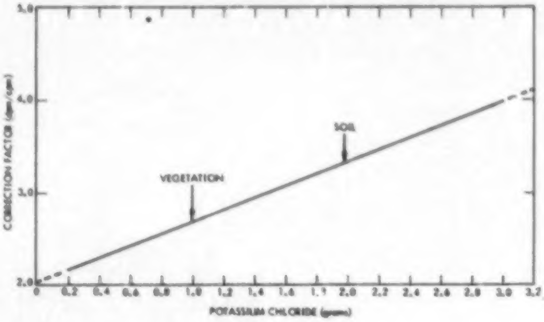

Figure 2. Sample self-absorption correction graph

Air monitoring

Environmental air sampling is conducted continuously at the headquarters and NDFL sites with automatic air samplers operating on 24-hour sampling cycles. Airborne particulate radioactivity is collected on HV-70 filter paper which is automatically changed at the end of each sampling period. The filter is removed from the sampler and counted after the radioactivity has been allowed to decay for at least 72 hours. The volume of a typical daily environmental air sample is approximately 20 cubic meters. The average concentration of long-lived beta-gamma radioactivity of airborne particulates is presented in table 2 for July–December 1970.

Table 2. Beta-gamma radioactivity of airborne particulates, Atomics International, July–December 1970

Location	Number of samples	Average concentration[a] (pCi/m³)
Headquarters	344	0.22
NDFL	1,222	.25

[a] Minimum detectable level—0.04 pCi/m³.

When abnormally high airborne radioactivities are observed, the radioactivity decay data are plotted to determine the presence of short-lived isotopes other than naturally occurring radon, thoron, and daughters. If fallout is suspected, the decay characteristics are observed. If the radioactivity decays as a function of $t^{-1.2}$, the data are extrapolated to determine the date of origin. This date is compared with the dates of publicized nuclear detonations to determine if the abnormal airborne radioactivity could have been caused by such detonations.

A graph of averaged long-lived airborne radioactivity concentrations detected at the Headquarters and NDFL facilities during the second half of 1970 is presented in figure 3. The graph shows a generally decreasing concentration trend through the fall months with a prominent peak noted in November.

Water monitoring

Process water used at the NDFL is obtained from Ventura County Water District No. 10 and distributed onsite by the same piping system previously used when process water was supplied by onsite wells. Pressure is provided by elevated storage tanks, one 50,000-gallon and one 500,000-gallon tank onsite. While clinically potable, the water is not used for drinking. Bottled potable water is delivered by a vendor and is not analyzed. Water from the pipe system is sampled monthly at two locations. The average process water radioactivity concentration is presented in table 3.

Soil, vegetation, and water are sampled monthly at Chatsworth Reservoir which is operated by the

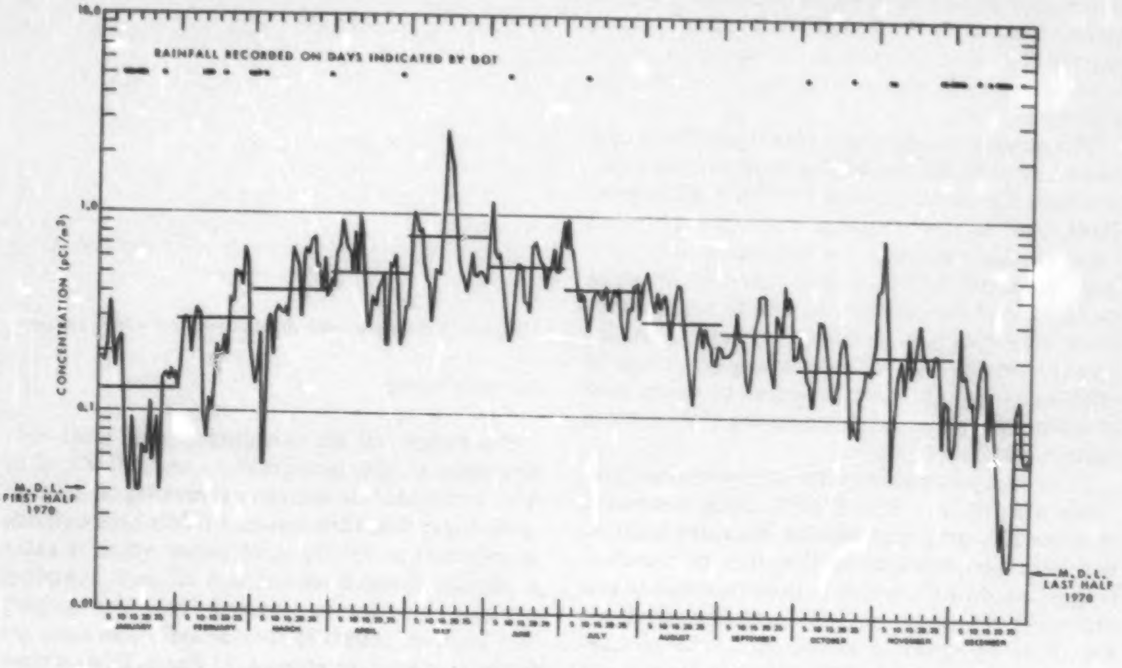

Figure 3. Long-lived radioactivity at Headquarters and NDFL, January–December 1970

Table 3. Process water radioactivity, NDFL site July–December 1970

Type of radioactivity	Number of samples	Average concentration (pCi/liter)
Alpha	12	0.30
Beta-gamma	12	4.9

Los Angeles City Department of Water and Power. Normally, one water sample is obtained from the lake surface, and a second sample is obtained from the reservoir water supply inlet located on the north side of the lake. The lake was drained in July 1969 for construction, thereby precluding surface sampling for all of 1970. The average radioactivity concentration in reservoir supply water samples is presented in table 4.

Table 4. Chatsworth Reservoir water radioactivity Atomics International, July–December 1970

Sample	Type of radioactivity	Number of samples	Average concentration (pCi/liter)
Lake surface	Alpha	0	–
	Beta-gamma	0	–
Supply inlet	Alpha	6	0.54
	Beta-gamma	6	4.9

Surface discharged waters from NDFL facilities drain into holding reservoirs on adjacent property. When full, the main reservoir is drained into Bell Creek, a tributary of the Los Angeles River in the San Fernando Valley, Los Angeles County. Pursuant to the requirements of Los Angeles Regional Water Quality Control Board Resolution 66-49 of September 21, 1966, an environmental sampling station has been established in Bell Creek Canyon approximately 2.5 miles downstream from the south NDFL boundary. Samples, obtained and analyzed monthly, include stream-bed mud, vegetation, and water. Average radioactivity concentrations in the main holding reservoir and Bell Creek samples are presented in table 5.

Soil and vegetation monitoring

Soil and vegetation are regularly sampled at 25 locations. Eleven sampling stations are located within the boundaries of Atomics International's sites and are referred to as "onsite" stations. The remaining 14 stations, located within a 10-mile radius of the sites, are referred to as "offsite" stations.

Table 5. Radioactivity in the Rocketdyne reservoir and Bell Creek,[a] July–December 1970

Sample description (units)	Number of samples	Alpha radioactivity	Beta radioactivity
Reservoir station 6, water[a] (pCi/liter)	6	0.24	7.1
Reservoir station 12, water[a] (pCi/liter)	6	.16	7.2
Bell Creek, mud (pCi/g)	6	.54	24
Bell Creek, vegetation (pCi/g ash)	6	.18	100
Bell Creek, water (pCi/liter)	6	.28	3.4

[a] Location not shown on figure 1.

Surface soil types that are available for sampling range from decomposed granite to clay and loam. Samples are taken from the top half-inch layer of ground surface. The soil samples are packaged and sealed in plastic containers and returned to the laboratory for analysis. Radioactivity in soil samples is presented in table 6.

Table 6. Radioactivity in the soil, Atomics International, July–December 1970

Area	Type of radioactivity	Number of samples	Average concentration (pCi/g)
Onsite	Alpha	72	0.54
	Beta-gamma	72	25
Offsite	Alpha	24	.55
	Beta-gamma	24	24

Vegetation samples obtained in the field are of the same plant type wherever possible, generally sunflower or wild tobacco plant leaves. These types maintain a more active growth rate during the dry season than do most natural vegetation indigenous to the local area. Vegetation leaves are stripped from plants and transferred to the laboratory for analysis. Plant root systems are not routinely sampled. Radioactivity in vegetation samples is presented in table 7.

Table 7. Radioactivity in vegetation, Atomics International, July–December 1970

Area	Type of radioactivity	Number of samples	Average concentration (pCi/g ash)
Onsite	Alpha	72	0.26
	Beta-gamma	72	150
Offsite	Alpha	24	.30
	Beta-gamma	23	120

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1969	August 1970
January–June 1970	February 1971

2. Hanford Atomic Products Operation[1]
January–December 1968

Battelle Memorial Institute
Richland, Wash.

A variety of radioactive wastes are generated by the Hanford production reactors, chemical separations plants, and laboratories. High-level wastes are concentrated and retained in storage within the project boundaries. Controlled releases of low-level wastes, for which concentration and storage are not feasible, are made to the ground, to the atmosphere, and to the Columbia River. The Atomic Energy Commission (AEC) regulations governing radioactive waste disposal at Hanford are described in the AEC Manual Chapter RL 0510 (*1*). During 1968, the plant facilities were operated for the Atomic Energy Commission by: Atlantic Richfield Hanford Company; Pacific Northwest Laboratories of Battelle Memorial Institute; Douglas-United Nuclear, Incorporated; and ITT Federal Support Services, Incorporated.

The Hanford site is in a semiarid region of southeastern Washington State (figure 4) where the average rainfall is about 16 cm (6 inches). This section of the State has a sparse covering of natural vegetation primarily suited for grazing, although large areas near the site have gradually been put under irrigation during the past few years. The plant site covers an area of about 1,300 km^2 (500 square miles). The Columbia River flows through the northern edge of the project and forms part of the eastern boundary. Prevailing winds near the plant production sites are from the northwest, with strong drainage and cross winds

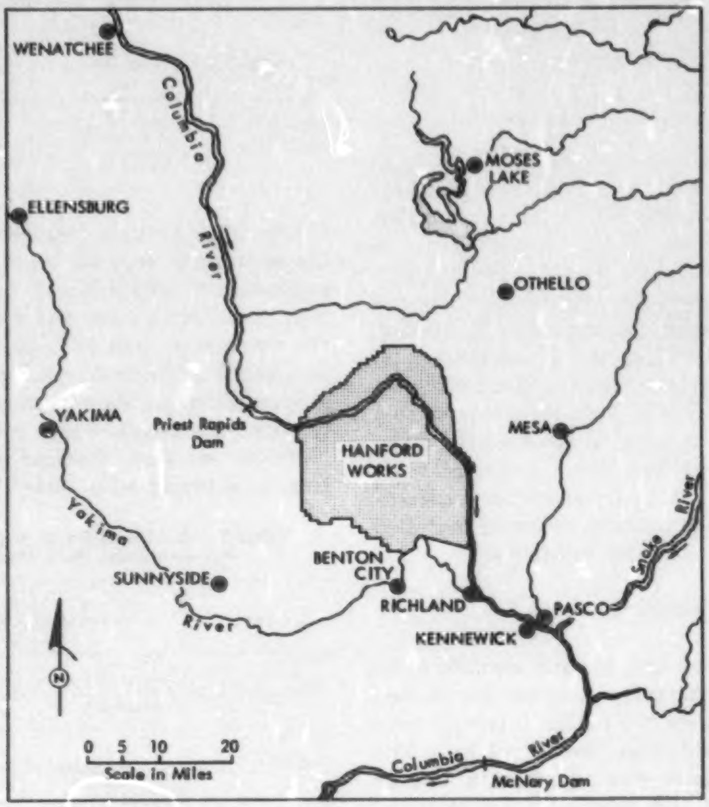
WENATCHEE
Columbia
River
MOSES LAKE
ELLENSBURG
OTHELLO
YAKIMA
Priest Rapids Dam
HANFORD WORKS
MESA
Snake River
Yakima
BENTON CITY
SUNNYSIDE
River
RICHLAND
PASCO
KENNEWICK
N
0 5 10 20
Scale in Miles
Columbia River
McNary Dam

Figure 4. Hanford project environs

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[1] Summarized from Pacific Northwest Laboratory, "Evaluation of Radiological Conditions in the Vicinity of Hanford for 1968," BNWL–1341 (May 1970).

causing distorted flow patterns. The meteorology of the region is typical of desert areas with frequent strong inversions occurring at night and breaking during the day to provide unstable and turbulent conditions.

The populated area of primary interest is the tri-cities area (Richland, Pasco, and Kennewick) situated on the Columbia River directly downstream from the plant. Smaller communities in the vicinity are Benton City, West Richland, Mesa, and Othello. The population of the communities near the plant, together with the surrounding agricultural area, is about 95,000.

Sources and levels of environmental radioactivity

Low-level wastes from plant operations, fallout from nuclear weapons testing, naturally occurring radioelements, and cosmic rays contribute to radioactivity in the Hanford environs. Hanford operations that could contribute to radioactivity outside the plant boundary are: (1) the disposal of reactor cooling water to the Columbia River, (2) stack releases at the chemical separations areas and laboratory areas, and (3) disposal of radioactive wastes to ground.

The most significant Hanford contributions to off-plant radioactivity and population doses usually originate with reactor cooling water released to the Columbia River. Although airborne releases of iodine-131 have contributed in past years to the thyroid doses of the local population, the major portion of the thyroid doses in 1968 resulted from radioiodines in drinking water.

Noteworthy events during 1968 included the retirement in mid-February of B reactor, the fifth Hanford production reactor to be retired since 1964. Four plutonium production reactors (including the dual-purpose N reactor) remained in operation. Increases in atmospheric total beta concentrations in January with sustained high concentrations throughout the first part of the year were attributed primarily to an announced foreign weapons test in December 1967 (*2*).

Radioactivity in the Columbia River

Nuclides present in reactor effluent

Cooling of the Hanford production reactors (with the exception of N reactor) is accomplished by a single pass of treated Columbia River water. The N reactor uses recirculating demineralized water as a primary coolant, and all wastewater containing significant amounts of radioactive material is discharged to a ground disposal site near the river. Although some of these radionuclides eventually enter the river, the total quantity of radioactivity entering the Columbia River from N reactor is a negligibly small fraction of that released from the older reactors.

At the older reactors, some elements present in the cooling water are activated during the single pass through the reactors. In addition, radioactive materials formed on the surfaces of fuel elements and process tubes are eventually carried away by the cooling water to the river. Table 8 shows the relative abundance of the radionuclides found in the cooling water of the older production reactors, adjusted to 4 hours after leaving the reactor.

Table 8. Relative abundance of reactor effluent radionuclides[a]

Percent of abundance				
Major (90 percent)	Minor (9 percent)	Trace (1 percent)		
^{24}Na	^{32}P	^{3}H	^{91}Y[b]	^{143}Ce[b]
^{31}Si	^{46}Sc	^{14}C	^{93}Y[b]	^{144}Ce[b]
^{51}Cr	^{69m}Zn	^{35}S	^{95}Nb	^{142}Pr[b]
^{56}Mn	^{72}Ga	^{45}Ca	^{99}Mo	^{143}Pr[b]
^{64}Cu	^{76}As	^{54}Mn	^{103}Ru	^{147}Nd[b]
	^{92}Sr	^{59}Fe	^{106}Ru	^{147}Pm[b]
	^{122}Sb	^{60}Co	^{124}Sb	^{149}Pm[b]
	^{133}I	^{65}Ni	^{131}I	^{151}Pm[b]
	^{140}La[b]	^{65}Zn	^{132}I	^{152}Eu[b]
	^{152m}Eu[b]	^{85m}Sr	^{135}I	^{156}Eu[b]
	^{153}Sm[b]	^{89}Sr	^{136}Cs	^{153}Gd[b]
	^{165}Dy[b]	^{90}Sr	^{137}Cs	^{159}Gd[b]
	^{239}Np	^{91}Sr	^{140}Ba	^{160}Tb[b]
		^{90}Y[b]	^{141}Ce[b]	^{161}Tb[b]
				^{166}Ho[b]
				^{169}Er[b]
				^{171}Er[b]

[a] Trace nuclide composition based on analyses, 1964 and 1968.

[b] These radionuclides as a group are denoted hereafter as RE+Y (rare earths+yttrium).

Many of the radionuclides formed in reactor cooling water are short-lived and disappear quickly due to radioactive decay. In addition, sedimentation and uptake by aquatic organisms remove some fraction of most radionuclides from the river water. The relatively small amounts of fission products present in the river can be attributed to the fissioning of natural uranium present in the river water, occasional ruptures of the fuel element jackets, and fallout from nuclear weapons testing.

Some radionuclides also enter the river from

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wastes disposed to ground, but their contribution to the total radioactivity is extremely small.

River flow rates

The seasonal fluctuations in flow rate of the Columbia River affect radionuclide concentrations by varying the quantity of water available for dilution of reactor effluent released to the river. In addition, the seasonal scouring of sediments deposited in reservoirs behind each dam causes seasonal fluctuations in transport rates of those longer-lived nuclides associated with the sediments. This is notably true for scandium-46 and zinc-65. Also affected by the flow rate is the time required for a specific volume of water to move from one location to another which in turn affects the amount of decay of the shorter-lived nuclides that will occur before these nuclides reach a particular location on the river.

The weekly average flow rates of the Columbia River at Priest Rapids and Bonneville Dams are determined from daily average flow rates published by the U.S. Geological Survey (*3*). For 1968, the average river flow rate at Priest Rapids was 3,380 m^3/s (120,000 ft^3/s), which was below the 1948–1962 annual average of 3,770 m^3/s (133,000 ft^3/s).

River concentrations

During 1968, samples of river water were collected above the production reactor areas at Priest Rapids Dam and below the areas at the Richland water plant intake, McNary Dam and Bonneville Dam. Where possible, cumulative sampling equipment was used to provide a more representative sample than periodic "grab" samples. This cumulative sampling technique, however, prevents calculation of the concentrations of radionuclides with very short half-lives; these were measured in monthly "grab" samples (*4*).

Table 9 shows the annual average radionuclide concentrations in river water at Richland and at Bonneville Dam for 1965–1968. The data for 1966 include the effects of reactor outages during the July–August strike. Comparison of 1968 with 1967 concentrations indicates a general reduction for most radionuclides. Part of the apparent reduction in phosphorus-32 at Richland is attributed to a change from "grab" to cumulative sampling. For example, the average of the cumulative samples during 1967 was 130 pCi/liter compared to 190 pCi/liter for "grab" samples of phosphorus-32. In 1968, concentrations of the short-lived radionuclides were expected to be lower than in previous years because fewer production reactors remained

Table 9. Annual average concentrations of several radionuclides in Columbia River water, 1965–1968

Radionuclide	Concentration (pCi/liter)							
	1965		1966		1967		1968[a]	
	Richland	Bonneville Dam	Richland	Bonneville Dam	Richland	Bonneville Dam	Richland	Bonneville Dam
Rare earths + yttrium	730	(b)	270	(b)	390	(b)	280	(b)
Hydrogen-3	(b)	(b)	(b)	(b)	1,500	(b)	1,700	(b)
Sodium-24	3,100	(b)	2,600	(b)	2,600	(b)	2,200	(b)
Phosphorus-32	140	23	140	23	190	25	92	15
Scandium-46	(b)	(b)	30	(b)	60	18	100	20
Chromium-51	7,000	1,700	3,600	1,300	3,200	1,400	1,500	530
Manganese-56	390	(b)	290	(b)	520	(b)	250	(b)
Copper-64	2,500	(b)	1,400	(b)	2,000	(b)	1,200	(b)
Zinc-65	180	70	200	43	220	62	86	<30
Arsenic-76	1,000	(b)	420	(b)	400	(b)	320	(b)
Strontium-90	1	(b)	1	(b)	1	(b)	< .6	(b)
Zirconium-niobium-95	(b)	(b)	(b)	(b)	(b)	<5	<6.3	(b)
Technetium-99	(b)	(b)	(b)	(b)	<5	(b)	<11	(b)
Ruthenium-106	(b)	(b)	(b)	(b)	(b)	<5	<5	(b)
Antimony-122	(b)	(b)	(b)	(b)	150	(b)	150	(b)
Iodine-131	10	3	18	3	8	3	7.4	<3.2
Neptunium-239	1,600	(b)	770	(b)	1,100	(b)	1,000	(b)
Total alpha	<1.1	(b)	<1.3	(b)	<1.2	(b)	[c]1.3	(b)

[a] During 1968, results for ^{3}H, ^{32}P, ^{46}Sc, ^{51}Cr, ^{65}Zn, ^{95}Zr-Nb, ^{90}Sr, and ^{131}I were based on cumulative samples.
[b] Indicates insufficient data to provide a meaningful annual average.
[c] Based on grab samples (January–June) and on cumulative samples (July–December).

in operation. Moreover, the operating reactors are farther upstream than the retired reactors (except "B" reactors). As in past years, total alpha concentrations measured in river water at Richland were near the analytical limit (1 pCi/liter) and were not significantly different from those measured in samples collected upstream from the Hanford project.

Concentrations of tritium in river water are measured upstream from Hanford at Priest Rapids Dam and downstream from Hanford at Richland. The average concentrations of tritium at Priest Rapids Dam and Richland were not significantly different at 1.6 and 1.7 nCi/liter, respectively, compared to 1.4 and 1.5 nCi/liter at these locations during 1967.

Sampling traverses across the Columbia River at Richland have indicated a slightly nonuniform distribution of the longer-lived radionuclides at this cross section. Entries of the Yakima River just below Richland and of the Snake River just below Pasco influence the distribution of radionuclides in the Columbia below these two points. The magnitude of the influence varies with seasonal changes in the flow rate of the tributaries.

Bonneville Dam, approximately 490 km (240 miles) below the Hanford reactors, is the farthest downstream location where river water is routinely sampled as part of the Hanford environmental surveillance program. Measurements at this location provide an upper limit to the annual transport of specific nuclides into the Pacific Ocean (table 10).

Table 10. Annual average transport rates of selected radionuclides past Bonneville Dam, 1964–1968

Radionuclides	Transport rate (Ci/day)				
	1964	1965	1966	1967	1968
Phosphorus-32	12	11	9	12	6.2
Scandium-46	NA	NA	NA	10	7.5
Chromium-51	860	800	430	610	200
Zinc-65	44	49	21	40	<13

NA, indicates no routine analysis was made.

Transport rates

Table 10 shows the annual average transport rates of selected radionuclides past Bonneville Dam. Transport rates of 84-day scandium-46 increased to detectable values in 1967. The transport rates at Richland in 1968 for the radionuclides shown were all lower than the 1967 values, primarily due to changes in reactor operation and the retirement of the "B" reactor.

Trend indicator—whitefish

The Columbia River is popular for sports fishing both above and below the Hanford reservation. Fish that feed downstream from the reactors acquire some reactor-effluent radionuclides through food chains with phosphorus-32 being the most significant in regard to population doses. Changes in river concentrations and temperatures may induce changes in concentrations in biological media. However, the ultimate uptake of radionuclides depends on complex environmental interrelationships. Whitefish is the sports fish that usually contains the greatest concentration of radioactive materials. Furthermore, it can be caught during winter months when other sports fish are difficult to sample. Therefore, phosphorus-32 data accumulated from whitefish sampling near the plant boundary are useful as a trend indicator of concentrations in biological media even though whitefish is not the most significant source of radionuclides for the local population.

Concentrations of phosphorus-32 in whitefish during 1968 tended to follow the same seasonal trends observed in past years. The average concentrations of phosphorus-32 in whitefish sampled downstream from the reactors during 1968 was 140 pCi/g, as compared with 260 pCi phosphorus-32/g during 1967 (*5*). The lower average phosphorus-32 concentration in 1968 was attributed to decreased concentrations of phosphorus-32 in the river and decreased river temperatures.

Radioactivity in groundwater

Radioactivity in the groundwater beneath the Hanford project results primarily from ground disposal of wastes in the chemical separations areas. These wastes are routed to various facilities dependent upon their radionuclide burden and chemical content. High-level wastes[4] are stored in underground concrete tanks lined with steel. Intermediate-level wastes[5] are sent to underground "cribs" (covered liquid waste disposal sites) from which they percolate into the soil. The areas selected for intermediate-level waste disposal and high-level waste storage have soil with good ion exchange capacity and groundwater depths of 50 to 100 m. Low-level wastes[6] are usually sent to depressions in the ground where surface ponds or "swamps" have been formed as the result of the continuous addition of relatively large volumes of water.

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[4] High-level: >100 μCi/ml.

One important objective in the management of wastes placed in the ground is the prevention of radiologically important radionuclides from reaching the groundwater in quantities that could ultimately cause significant human radiation exposure should they migrate to the Columbia River. An extensive groundwater surveillance program is maintained at Hanford to aid in achieving this objective. Hundreds of wells have been drilled at various locations around the Hanford project, including sites within and near crib and tank storage areas, to monitor the movement of radionuclides in the groundwater.

The radioactivity in groundwater from the chemical separations areas outside the immediate vicinity of the disposal sites is primarily tritium and ruthenium-rhodium-106, although cobalt-60 and technetium-99 have also been found but at much lower concentrations. The more radiotoxic nuclides, such as strontium-90, have not been detected in groundwater except in the immediate vicinity of a few specific disposal sites.

Figures 5 and 6 show the probable extent of detectable tritium and ruthenium-rhodium-106 in groundwater beneath the Hanford project as of December 31, 1968 (*6*). The outer boundaries of the contamination contours, e.g., 0.1 percent for tritium and 2 percent for ruthenium-rhodium-106, represent the detection levels routinely achievable for these radionuclides (*1*).

In all probability, some radionuclides from the chemical processing areas are presently entering the Columbia River. However, the concentrations of these nuclides are too small to be routinely measurable in the groundwater near the river or in the river itself, and any radiation dose from them is negligible.

Radioactivity in the atmosphere

At Hanford, gaseous wastes from the chemical separations facilities are released to the atmosphere through elevated stacks after most of the radioactive materials have been removed. Laboratory stacks, reactor-building stacks, and stacks from waste-storage facilities release relatively minor amounts of radioactive materials under normal operating conditions.

Measurements of airborne iodine-131, the radionuclide of primary interest, were made routinely during 1968 at about 30 locations within and near the Hanford reservation. The results of iodine-131 measurements for four selected locations for the past few years, which include contributions from offsite weapons tests, are summarized in table 11. The locations listed in table 11 lie within a 45° sector southeast to south of the separations areas. The environmental iodine-131 concentrations for 1968 averaged less than the analytical limit of 0.02 pCi/m^3 at Richland, Pasco, and Kennewick. A sustained concentration of iodine-131 at this level in breathing air would imply an annual radiation dose to the thyroid of the standard man of less than 1 mrem from inspired air[7] (*7*).

Continuous sampling for radioactivity associated with airborne particulates was maintained as of the end of 1968 at 35 locations, including those within the Hanford reservation and around the plant perimeter at distances up to 75 miles.

Table 11. Annual average iodine-131 concentrations in the atmosphere, 1964–1968

Location	Distance from separation stacks (miles)	Iodine-131 (pCi/m^3)				
		1964	1965	1966	1967	1968
Prosser barricade[a]	14	0.02	0.03	0.02	0.02	0.01
Benton City	20	.06	.03	.01	.02	.01
Richland	20	.02	.02	.01	.02	.02
Pasco	32	.01	.03	.01	.02	.02

[a] Sampling was discontinued in April 1968.

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[5] Intermediate-level: 50 pCi/ml to 100 μCi/ml.

[6] Low-level: <50 pCi/ml.

[7] Assuming that volume breathing rate is proportional to thyroid size, the thyroid dose from inhalation of iodine-131 is independent of age and thyroid size (*8*).

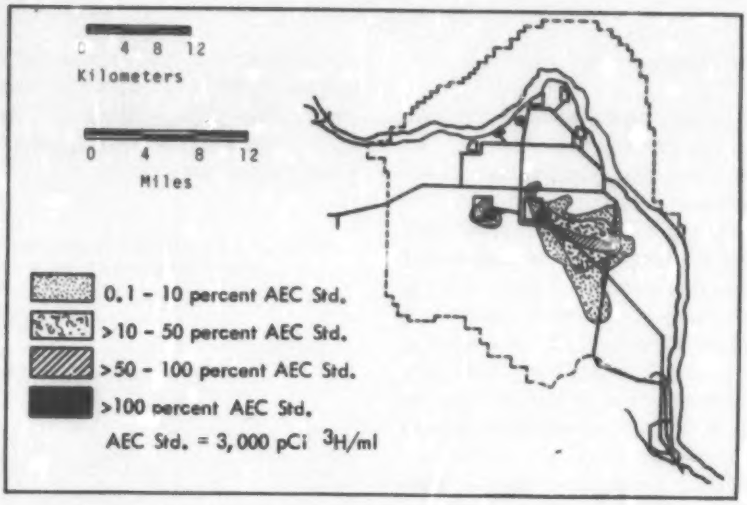
0 4 8 12
Kilometers
0 4 8 12
Miles
0.1 - 10 percent AEC Std.
>10 - 50 percent AEC Std.
>50 - 100 percent AEC Std.
>100 percent AEC Std.
AEC Std. = 3,000 pCi ^{3}H/ml

Figure 5. Tritium concentrations in ground water, Hanford July–December 1968

The gross beta activity of each sample filter was routinely measured (based on strontium-yttrium-90 standard) with detailed radioanalyses performed on filters showing unusual beta radioactivity.

The higher atmospheric concentrations of radioactive particulate material during the first half of 1968 compared to fall 1967 were attributed primarily to fallout following a foreign nuclear weapons test in late December 1967. The observed concentrations were comparable to those observed during similar events of recent years. A similar increase in total beta concentrations was noted in December 1968; however, no significant increase was noted in the Southeast quadrant locations because of the nonuniform geographical distribution of increased concentrations. The increase was attributed to fallout from an offsite source and the contaminant was identified as radiotungsten.

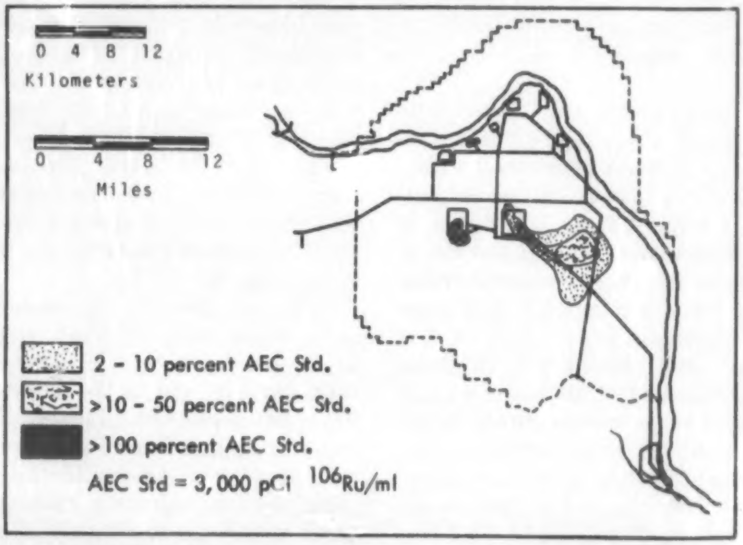
0 4 8 12
Kilometers
0 4 8 12
Miles
2 - 10 percent AEC Std.
>10 - 50 percent AEC Std.
>100 percent AEC Std.
AEC Std = 3,000 pCi ^{106}Ru/ml

Figure 6. Ruthenium-106 concentrations in ground water, Hanford July–December 1968

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Fallout from nuclear weapons tests

Fresh fallout in early 1968, resulted from an announced foreign nuclear weapons test in December 1967 (*2*). Airborne particulate radioactivity concentrations were higher during the first half of 1968 as a result of the December 1967 event. Atmospheric concentrations of iodine-131 were within the normal range of fluctuation from plant sources, but iodine-131 concentrations in milk samples reached a peak of 25 pCi/liter in January. For comparison, in January 1967, the peak iodine-131 concentration in milk was 83 pCi/liter as a result of fallout from a foreign weapons test in December 1966.

In December 1968, a general increase in beta radioactivity in the atmosphere was attributed to regional fallout from an event at the Nevada Test Site with the highest concentration of particulate radioactivity (3.9 pCi/m^3) at Walla Walla during the period, December 6 through December 20, 1968 (*2*). The principal gamma-emitter was identified as radiotungsten.

No significant contribution to atmospheric radiation levels was detected in December samples following the announced foreign nuclear weapons test of December 27, 1968 (*9*).

Exposure pathways

Radionuclides in drinking water

The city of Richland is the first community downstream from the Hanford reactors that uses the Columbia River as a source of drinking water. Pasco and Kennewick, a few kilometers farther downstream, also use the Columbia River as a source of drinking water. The Richland and Pasco water plants use a modern flocculation-filtration method; Kennewick water is pumped from Rainey well collectors (infiltration pipes) laid in the riverbank. During 1968, cumulative drinking water samples were collected at the Richland and Pasco water plants and periodic samples at all three communities. All of these samples were analyzed for important individual radionuclides. Detailed analyses of drinking water from these three cities are summarized in table 12. In June, analyses of individual radionuclides in samples from Kennewick were discontinued because previous experience had shown that concentrations of radionuclides in Kennewick water were significantly lower than those at Pasco or Richland. Kennewick samples continued to be analyzed for gross beta radioactivity.

Table 12. Average concentrations[a] of several radionuclides in drinking water, 1968

Radionuclide	Radioactivity concentration (pCi/liter)		
	Richland	Pasco	Kennewick[b]
Rare earths + yttrium	46	20	9
Sodium-24	1,000	350	140
Phosphorus-32	48	30	13
Chromium-51[c]	1,400	1,400	480
Copper-64	350	<51	38
Zinc-65[c]	38	35	<24
Arsenic-76	140	33	15
Strontium-90[c]	<0.6	<0.5	NA
Antimony-122	120	100	22
Iodine-131[c]	6.9	5.9	<2
Iodine-133	[d]41	[e]24	NA
Neptunium-239	670	340	57
Total beta, counts/min-ml	2.9	1.2	.3

[a] Measured at the water plants.

[b] Kennewick concentrations were based on monthly grab samples collected January through June except for total beta which was based on weekly grab samples throughout the year.

[c] Results based on cumulative samples at Richland and Pasco.

[d] Estimate based on an average ratio of ^{133}I/^{131}I of 6:1 measured in grab samples.

[e] Estimate based on an average ratio of ^{133}I/^{131}I of 4:1 measured in grab samples.

NA, no analysis.

The concentrations of short-lived radionuclides in the water at the time it is consumed are less than shown in table 12 because there can be a significant transport time between the water plant and most consumers. The transport time may vary from hours to days depending upon the location of the customers on the distribution system and the water demand. In Richland, many residents receive no radioactivity of Hanford origin in drinking water during the times of the year when well water is used to supplement the system supply.

Table 13 presents calculated doses to the adult whole body, GI tract, and bone from sustained consumption at a standard intake of 1.2 liters per day, and to the infant-2 gram thyroid from consumption of 0.4 liters per day of drinking water in Richland and Pasco. Average concentrations of radionuclides measured at the water plants were used to calculate these doses. However, thrice-weekly measurements of gross beta radioactivity were also used in establishing the GI-tract dose.

The dose estimates for Pasco residents reflect a downward trend from 1967. The thyroid dose for 1968 from Pasco drinking water (32 mrem) was slightly less than that for 1967 (35 mrem) because of the decreased concentration of iodine-131. The average ratio of iodine-133 to iodine-131 of 4:1 for Pasco in 1968, which was based on 1968 measurements on grab samples, was the same as the assumed ratio in 1967.

Table 13. Calculated annual doses to selected organs from routine ingestion of drinking water, 1968[a]

Location	Whole body (mrem)	GI tract (mrem)	Bone (percent of MPRI)	Thyroid (infant) (0.4 liters/day) (mrem)
Richland	1.5	18	4.0 (0.1)	48
Pasco	0.5	12	2.5 (<0.1)	32

[a] The "standard man" (*80*) average intake rate of 1.2 liters/day was used in this calculation with the exception of the thyroid.

The estimated GI tract dose to Richland residents from the measured radionuclides in drinking water was somewhat lower in 1968 (18 mrem) than in 1967 (28 mrem) as a result of the decreased concentrations of most measured radionuclides and a decrease in the average gross beta radioactivity from 4.7 in 1967 to 2.9 counts/min-ml in 1968. The infant thyroid dose appears somewhat higher during 1968 than during 1967 because the estimated contribution of iodine-133 was based on an assumed ratio of iodine-133 to iodine-131 of 4:1 in 1967 (*5*). Measurements during 1968, however, indicated a slightly higher ratio (6:1). Without the increment from iodine-133, the estimated thyroid dose for 1968 would have been lower than for 1967.

Radionuclides in Columbia River fish

The quantities and kinds of fish caught by local fishermen have been previously estimated from surveys carried out from 1963 to 1965 in cooperation with the Washington State Game Department. The maximum estimate of consumption by the fishermen interviewed was 200 meals per year of panfish species (crappie, perch, and bass) taken from the Columbia River. Additional dietary data collected during 1966 and 1967 from household questionnaires and interview surveys also showed individual consumption estimates as high as 200 meals of fish per year.[8] The primary fishing locations for the catch of these fish were Burbank, Hover-Finley, and Island View. The average percentage of the maximum catch by species was 73 percent crappie, 16 percent bass, and 11 percent perch.

From this species distribution and radiochemical analyses of the specimens collected, the "maximum individual's"[9] estimated intakes during 1968 were 1.0 μCi phosphorus-32 and 0.4 μCi zinc-65 (*4*).

The average consumption of Columbia River fish by Richland residents was estimated from plant employee diet questionnaires (*5*). With the use of the same mixture of species as for the "maximum individual," the "average Richland resident's"[10] intake during 1968 was 0.012 μCi phosphorus-32 and 0.004 μCi zinc-65. Such an intake corresponds to a bone dose of slightly more than 2 mrem or about 0.5 percent of the standard of 500 mrem per year for the population average. For comparison, intakes during 1967 were 0.019 μCi phosphorus-32 and 0.004 μCi zinc-65.

Radionuclides in game birds

Migratory waterfowl utilizing the river downstream from the reactors and upland game birds living near the river may be a significant source of the bone-seeking radionuclides (phosphorus-32 and zinc-65) for persons who consume such birds. The concentrations of radionuclides in game birds at the time of consumption are dependent upon the bird species, the geographical locations of the birds, and the elapsed time between killing and consumption of the birds.

For the past 2 years, about 16 km² (4,000 acres) of the Hanford site situated north of Ringold on the eastern side of the Columbia River has been opened to hunters during hunting seasons. This area which is adjacent to the river was visited in 1968 by 1,537 hunters for an average of about 33 hunters on each of the 46 open days (*10*). For comparison, the average for 1967 was about 50 hunters on each of the 48 open days (*10*).

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[8] Fisherman survey by J. K. Soldat, Battelle-Northwest, Richland, Wash. (report in preparation).

[9] See page 356 for definition of term.

[10] See page 359 for definition of term.

The average concentration of phosphorus-32 in the muscle (the edible portion) of waterfowl collected at the Hanford site for the environmental monitoring program during 1968 was about 53 pCi/g for ducks and 1.4 pCi/g for geese. The maximum concentration in waterfowl during 1968 was 450 pCi phosphorus-32/g, which is significantly lower than the maxima observed in the past few years. Average concentrations in muscle for upland game birds collected at the Hanford site appear in table 14. The maximum phosphorus-32 concentration in upland game bird muscle was 490 pCi phosphorus-32/g in a quail sample. If a small child (2 kg skeleton) had immediately consumed 100 grams of this quail, the resultant bone dose would be about 30 mrem or 2 percent of the standard.

Table 14. Average phosphorus-32 and zinc-65 concentrations[a] in muscle of river birds, 1968

Species	Concentration (pCi/g)	
	Phosphorus-32	Zinc-65
Duck	53	3.3
Goose	1.4	1.5
Quail	41	3.5
Pheasant	10	4.9
Chukar	10.1	5.2

[a] Collected within 5 km (3 miles) of the Columbia River within the Hanford boundary.

Data from a dietary survey of Hanford employees and from a special survey of local hunters and concentration data for the various species have been combined in tables 15 and 16 (*4*, *5*, *10*).

Table 15. Distribution by species of local game birds, 1968

	Duck	Goose	Quail	Pheasant	Grouse	Dove
River birds[a] of each species	37	32	19	33	8	20
Meals of each species of all bird meals	23	6	12	47	13	ND
River bird meals of each species of all bird meals	8.5	1.8	2.3	16	<1	ND

[a] River birds are defined to be birds shot within 5 km (3 miles) of the Columbia River between Ringold and McNary Dam.
ND, no data.

About 30 percent of the game bird meals consumed by local hunters were reported to be birds shot within about 5 km (3 miles) of the Columbia River between Ringold and McNary Dam. Analyses showed that pheasants collected beyond this distance contained little if any radioactivity of Hanford origin. About 44 percent of all birds eaten were reported to have been placed in frozen storage which would permit appreciable decay of phosphorus-32 before consumption.

Table 16. Contribution of each species to 100 grams of an average game bird meal,[a] 1968

Species	Weight (grams)	Radionuclide content (pCi/g)	
		Phosphorus-32	Zinc-65
Duck	23	252	28
Goose	6	2	3
Quail	12	52	8
Pheasant	47	91	76
Grouse	13	5	5
Total	100	402	120

[a] Weighted for location of kill by using measured concentrations for river birds and assuming no phosphorus-32 or zinc-65 in other birds. Also weighted for frozen storage by assuming complete decay of phosphorus-32 but no significant decay of zinc-65 during frozen storage of 44 percent of the birds.

The maximum total game bird consumption by adults reported to date is 100 meals per year, which we assume to be about 23 kg/a. Consumption of this weight of the average game bird meal (table 15) would result in intakes of 0.09 μCi phosphorus-32 per year and 0.04 μCi zinc-65 per year, implying 14 mrem to the skeleton of a "standard man" or 1 percent of the standard for individual members of the population with bone as the critical organ. Consumption of the estimated annual intake (1.24 kg/a) for the "average Richland resident" (adult) would result in a total dose of less than 1 mrem to the skeleton.

Radionuclides in shellfish

Zinc-65 and phosphorus-32 are the only radionuclides in the reactor effluent that are found in sufficient abundance in food organisms beyond the mouth of the Columbia River to be of radiological interest. Oysters have been found to contain higher concentrations of zinc-65 than other common seafoods (*11*). Monthly average concentrations of zinc-65 and phosphorus-32 were periodically measured in oysters grown commercially in the Willapa Bay area. A normal seasonal minimum for phosphorus occurs in the late summer. In 1968, phosphorus-32 average concentrations remained at or below 1 pCi/g and from August through December as in 1967. The annual average concentrations for 1968 were 25 pCi zinc-65/g and 3.3 pCi phosphorus-32/g.

Consumption of oysters containing the 1968 average concentrations at the rate of 50 g/day would result in annual doses of about 5 mrem to the GI tract, 3 mrem to the whole body, and 8 mrem to the bone of a standard man (*12*, *6*). Fresh shellfish are not an important item in the average tri-cities diet, but residents of some coastal areas may consume more than the reference value of 50 g/day. For such individuals, shellfish are assumed to be their only source of radionuclides of Hanford origin.

Radionuclides in milk and produce

Irrigation with river water containing reactor effluent radionuclides can influence the radioactivity found in locally grown products. Deposition of airborne materials from Hanford sources and from fallout can be an additional source of radionuclides in these products. Chemical separations facilities are generally the principal local source of airborne radionuclides, although radioactive materials released from ventilation stacks of reactor or laboratory facilities could, under certain conditions, be of interest.

The farming area closest to the separations facilities is at Ringold about 21 km (13 miles) away. However, much of the land east and south of the project boundary is under cultivation and may be in the path of airborne release.

Most irrigated farms near the Hanford plant obtain water from the Yakima River or from the Columbia River above the plant. However, two small irrigated areas using Columbia River water taken downstream from the reactors are the Ringold farms and the Riverview district west of Pasco. They are 40 to 65 km (25 and 40 miles), respectively, downstream from the operating reactors. The Ringold farms, about 21 km east of the separations areas, involve some 20 people working 2 km^2 (500 acres) of land with fruit as the principal product. The Riverview district comprises about 21 km^2 (5,300 acres) supporting about 1,000 families, the majority of which live on plots of 4,000 m^2 (1 acre) or less and raise family gardens. The principal products from the larger farm plots are hay, fruit, beef, and diary products. This area is centered 40 km (25 miles) southeast of the chemical separations plants.

The milk surveillance program maintained during 1968 included samples from local farms and dairies and from commercial supplies available to people in the tri-cities. The concentrations of radionuclides found in milk sold by commerical outlets were similar to those reported by the U.S. Public Health Service and the Washington State Department of Health (*13*, *14*). Milk from local farms irrigated with water drawn from the river downstream from the reactors contained phosphorus-32, zinc-65, and iodine-131, as well as fission products of fallout origin. Commercial milk distributed in the tri-cities usually does not contain detectable phosphorus-32 and zinc-65 because the majority of the milk is produced on farms not irrigated with Columbia River water.

During 1968, the annual average phosphorus-32 concentrations was 450 pCi/liter compared to 320 pCi/liter in 1967 as a result of inclusion of another sampling location in 1968. The 1968 annual average concentration of zinc-65 was 340 pCi/liter compared to 200 pCi/liter for 1967. Seasonal fluctuations in concentrations of both phosphorus-32 and zinc-65, caused primarily by irrigation and feeding practices, followed expected trends.

During 1968, iodine-131 concentrations in both farm milk and commercial milk were generally near or below the analytical limit (3 pCi/liter). The maximum iodine-131 concentration for the period (25 pCi/liter) was measured in a single sample of farm milk collected on January 17 and was attributed to increased worldwide fallout. The average concentration for the year in farm milk was <1.5 pCi iodine-131/liter.

Adult residents consuming milk (1 liter/day) obtained from the Riverview area could have received an annual dose from phosphorus-32 and zinc-65 amounting to about 4 mrem to the GI tract, 2 mrem to the whole body, and 32 mrem to the bone. The same intake of milk by a child with a 2 kg skeleton would result in an estimated bone dose of 110 mrem.[11] The intake of iodine-131 would have resulted in a dose of about 9 mrem to the 2 g thyroid of an infant.

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[11] Based on dose factors of 660 mrem/μCi for phosphorus-32 and 11 mrem/μCi for zinc-65 for the 2 kg skeletal weight.

Miscellaneous fresh produce from local farms was sampled periodically for radioanalysis during the 1968 growing season. Results of these measurements were similar to those of previous years and indicated that only small quantities of radionuclides are present in locally grown produce.

Specifically, the concentrations of iodine-131 found in samples of fresh leafy vegetables collected from local farms and markets during the period of May through September were less than or approximately equal to the analytical limit of 0.05 pCi/g. Based on an assumed average concentration of one-half the analytical limit and the consumption of 100 g/day throughout the year, the annual intake from this source would have been about 380 pCi of iodine-131. Such an intake would imply an annual dose of about 0.6 mrem to the thyroid of an adult. Consumption of 50 g/day of the same vegetables by a small child would imply an annual dose of about 4 mrem to a 2 g thyroid.

External radiation

Ionization chambers (Victoreen stray radiation chambers) stationed on the Hanford reservation and in Richland measure the gamma radiation exposure from external sources. Measurements in air 1 meter above ground level during 1968 averaged about 0.36 mR/day or 130 mR/a at Hanford and 0.28 R/day or 100 mR/a at Richland. These were not significantly different from 1966 or 1967 values. Essentially all of the exposure at Richland is from natural background and worldwide fallout from nuclear testing.

Estimates of the external radiation dose received from recreational use of the Columbia River in the vicinity of the Hanford project is made from routine measurements at the river shoreline and below the surface of the river. The shoreline measurements are made with a large (40 liter) ionization chamber centered at 1 m (about 3 feet) above the ground to approximate the dose to the gonads.

The measured radiation includes components from radioactivity accumulated in sediment deposits and algal growths on the substrate at the river's edge. Gamma spectra show that scandium-46 and zinc-65 were the major contributors to the shoreline component and sodium-24 to the water component during 1968. The external exposure rate to swimmers, water skiers, and fishermen using the Columbia River in the tri-cities areas is predominately due to gamma rays of the order of 1 MeV or greater.[12] The shoreline radiation levels are affected by both the daily and seasonal fluctuations in the flow rate and river level.

The primary fishing locations for the panfish species consumed in the largest quantities are downstream from Richland, and the average dose rate for such fishermen is determined best from measurements at Sacajawea Park. During 1968, the average exposure rate at Sacajawea Park was 0.65 mR/day (27 μR/h) with an estimated 0.19 mR/day (8 μR/h) due to natural background radiation. An avid fisherman standing on the river shoreline at Sacajawea Park for as much as 500 hours during the year would have had a gonad and torso exposure to gamma radiation of about 10 mR (2 percent of standard for whole body), not including natural background radiation.

Direct radiation measurements also are made in the Columbia River at several locations with clusters of five pocket-type ionization chambers positioned about 1 meter (3 feet) above the river bottom. Exposure rates are primarily due to the gamma emitters (especially sodium-24) introduced into the river with reactor cooling water. In the vicinity of Richland, the average exposure rate in the water from April through October of 1968 was about 1.5 mR/day.

During 1967, the whole-body dose received by the average Richland resident from recreational use of the Columbia River was based on an estimated 24-hour immersion exposure time and was about 2 mrem. During 1968, a slightly different approach was used.

Teenagers were considered to be the major recreational users of the river. A recent survey of 430 Richland teenagers indicated an average exposure time for this group of about 115 hours of which about one-third of the time was probably immersion and about two-thirds was shoreline exposure.[13]

Using the annual shoreline exposure rates at Richland of 0.91 mR/day or 0.038 mR/h (not including background radiation) and the April-October average immersion exposure rate of 1.5 mR/day or 0.062 mR/h, the average exposure to the teenage population was estimated to be about 5 mR during 1968.

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[12] Unpublished shoreline data by D. H. Denham, Battelle-Northwest, Richland, Wash. (1969).

[13] Unpublished recreational use data by J. F. Honstead, Battelle-Northwest, Richland, Wash. (1969).

Some teenagers reported considerably greater exposure time than the average. The 38 teenagers reporting greater than 300 h/a total of Columbia River recreation time were taken to be a representative sample of the critical population group for this exposure pathway. The estimated annual whole-body doses for individual members of this group ranged from 6 to 37 mrem with an average of about 17 mrem compared to the appropriate standard (500 mrem/a). This represents less than 4 percent of the standard.

The average whole-body dose received by the Richland population from recreational use of the Columbia River can be estimated by assuming that other age groups use the river less than teenagers but with the same proportion of immersion and shoreline exposure times. Based on 11 hours of immersion and 21 hours of shoreline exposure in the vicinity of Richland, this whole-body dose during 1968 was estimated to be about 2 mrem, less than 1 percent of the appropriate standard of 170 mrem/a.

For comparison, if the recreational dose received by Richland residents were estimated for 1968 by the methods used in previous reports, the resulting whole-body dose would also be about 2 mrem.

Fallout from nuclear weapons tests

Dose increments received by residents of the Hanford environs from the fallout nuclides; tritium, strontium-90, and cesium-137 have been estimated routinely, although they are not included in the assessment of dose due to Hanford operations. Locally, this increment is below the national average because of the low rainfall. Measurements of fallout, like measurements of natural background radiation, help to put the radiation doses resulting from Hanford operations in proper perspective.

During the early influx of fresh fallout in 1968 following a foreign weapons test in December 1967, the peak iodine-131 concentration in milk was 25 pCi/liter compared to 83 pCi/liter in January 1967, following a foreign weapons test of December 1966.

Estimates of tritium intake from drinking water were based on concentrations measured in river water. Strontium-90 in locally available milk averaged slightly above 4 pCi/liter during 1968 and slightly below that in 1967. Concentrations of cesium-137 in locally available milk were generally near the analytical limit of 30 pCi/liter during both 1968 and 1967. Worldwide fallout is the source of strontium-90 and cesium-137 in milk.

Using the assumption that 40 percent of the total strontium-90 intake from fallout is obtained from milk, the daily intake of strontium-90 during 1968 was about 10 pCi/day for the "maximum individual," 10 pCi/day for the "typical Richland resident," and 5 pCi/day for the "average Richland resident" (adult) (*15*). These values are similar to the intakes estimated for 1967 (8, 9, and 5 pCi/day, respectively). The total intake of cesium-137 during 1968 was about 0.06 μCi for the "maximum individual," 0.01 μCi for the "typical Richland resident," and 0.01 μCi for the "average adult Richland resident." These intakes are also similar to those for 1967.

Tables 17 and 18 show a summary of the estimated annual doses from fallout nuclides present in the Hanford environs. The strontium-90 intakes are also evaluated in terms of the Federal Radiation Council guides (*16*).

Table 17. Annual radiation dose from fallout radionuclides,[a] 1968

Radionuclide	Organ	Radiation dose (mrem)		
		"Maximum" individual	"Typical" Richland resident	"Average" Richland resident
Tritium	Whole body	<1	<1	<1
Strontium-90[b]	Whole body	3	3	2
	GI tract	<1	<1	<1
	Bone	35	35	18
Cesium-137	Whole body	2	<1	<1
	GI tract	<1	<1	<1
	Bone	4	1	1

[a] Not included in dose summaries presented elsewhere.

[b] The values listed for dose to bone and whole body from ^{90}Sr are based on the assumption of an equilibrium situation, although such equilibrium would be approached only after many years of continuous intake. Average intakes for the "maximum" individual, the "typical" Richland resident, and the "average" adult Richland resident correspond to 2 percent, 5 percent, and 3 percent of the FRC guide (*23*) of 200 pCi/day for the average intake by a suitable sample of the exposed population or 600 pCi/day intake by an individual.

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Table 18. Total annual radiation doses from fallout radionuclides, 1967–1968

Organ	Radiation dose (mrem)					
	"Maximum" individual		"Typical" Richland resident		"Average" Richland resident	
	1967	1968	1967	1968	1967	1968
Whole body	5	5	3	4	2	3
GI tract	<1	<1	<1	<1	<1	<1
Bone	34	[a]40	32	36	19	19

[a] Number was rounded after summing contributions of strontium-90 and cesium-137.

Composite estimates of radiation dose

The "maximum individual"

Experience accumulated from the environmental surveillance program and associated research studies indicates that those individuals receiving the greatest percentage of permissible radiation dose from Hanford sources consume some combination of the following: fish caught locally in the Columbia River; game birds shot near the river; foodstuffs produced on local farms irrigated with Columbia River water drawn from below the reactors; and municipal water with the Columbia River as the source. A hypothetical "maximum" individual has been assigned assumed dietary habits (table 19) which are identical to those used in the 1966 and 1967 annual reports (*17, 5*) and have been documented separately in detail (*18, 19*).

The consumption rates of most foods for this hypothetical "maximum" individual were compiled from intake rates described in published dietary surveys. The postulated sources include water from the Pasco municipal system, milk, meat, and produce from river-irrigated farms in the Riverview district. The consumption of 200 meals per year of panfish taken from the Columbia

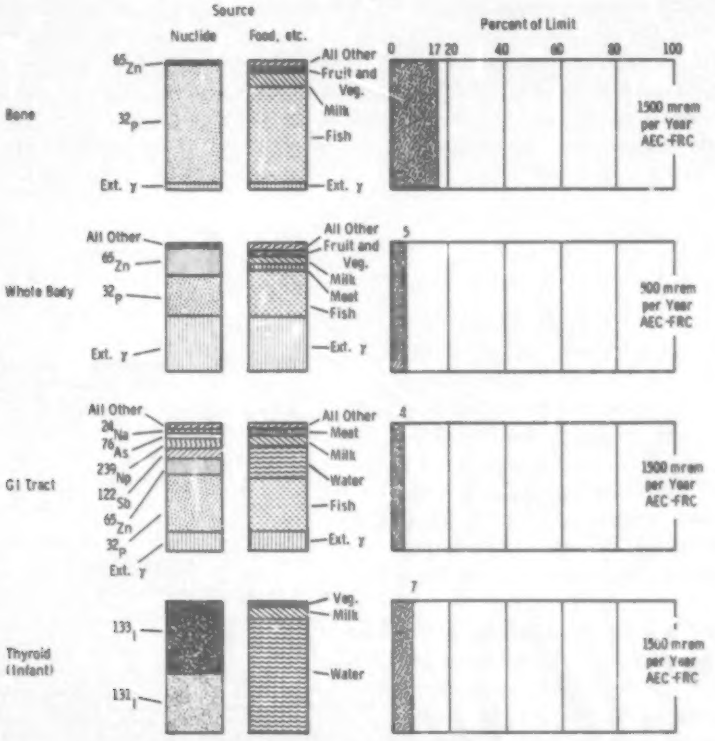

Figure 7. Estimated doses to the "maximum" individual, 1968

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Table 19. Dietary assumptions, 1968

Foodstuffs	"Maximum" individual	"Typical" (adult) Richland resident	"Average" (adult) Richland resident
Water	730 liter/a	440 liter/a	[a]680 liter/a
Milk	380 liter/a	310 liter/a	[a]130 liter/a
Meat	80 kg/a	80 kg/a	[a]74 kg/a
Chicken	8 kg/a	5.4 kg/a	[a]5.4 kg/a
Eggs	30 kg/a	15 kg/a	15 kg/a
Seafood	0	[b]5.5 kg/a	[ab]1.4 kg/a
Columbia River fish	40 kg/a	0	[a].48 kg/a
Game birds	0	0	[a]1.2 kg/a
Leafy vegetables	[c]73 kg/a	36.5 kg/a	36.5 kg/a
Other vegetables and fruits	[c]530 kg/a	[d]200 kg/a	[d]200 kg/a
Foodstuffs	**"Maximum" individual (infant)**	**"Typical" (infant) Richland resident**	**"Average" (infant) Richland resident**
Water	0.8 liter/day	0.4 liter/day	0.4 liter/day
Milk	1.0 liter/day	.6 liter/day	.6 liter/day
Leafy vegetables	50 g/day	25 g/day	25 g/day

[a] Based on dietary questionnaires of Richland residents employed at Hanford.

[b] One-tenth of the total is assumed to be Willapa Bay Oysters, the remainder free of radionuclides of Hanford origin.

[c] Fresh produce from the Riverview area is assumed to be available only during 5 months of the year.

[d] The previous report erroneously quoted 35.5 kg/a instead of 200 kg/a.

River is based on the maximum reported in local surveys. A total of 500 h/a along the riverbank to catch these fish is also assumed.

The composite dose for this "maximum" individual is summarized in table 20 and illustrated in figure 7. The estimated dose to the GI tract for the "maximum" individual during 1968 was about 62 mrem or about 4 percent of the appropriate standard, which is slightly lower than the 1967 GI tract dose which was about 5 percent of the standard. The whole-body dose estimated for 1968, 24 mrem or about 5 percent of the appropriate standard, was somewhat lower than the 1967 estimate of 32 mrem (6 percent of standard).

Table 20. Summary of radiation doses in the Hanford environs,[a] 1968

Organ	Annual dose (mrem)	Standard (mrem)	Percent of standards
Maximum individual:			
Bone	250	1,500	17
Whole-body	24	500	5
GI tract	62	1,500	4
Thyroid (infant)	110	1,500	7
Typical Richland resident:			
Bone	8	500	2
Whole-body	3	170	2
GI tract	24	500	5
Thyroid (infant)	55	500	11
Average Richland resident:			
Bone	13	500	3
Whole-body	3	170	2
GI tract	25	500	5
Thyroid (infant)	39	500	8

[a] Doses from fallout and natural background not included.

The estimated percent of the maximum permissible rate of intake (for ingested radionuclides) with bone as the critical organ was 9 percent during 1968, compared to 12 percent during 1967, and 10 percent during 1966. However, for purposes of this report, an estimated bone dose of 250 mrem (17 percent of the FRC Standards) was derived from radionuclide intake and included a contribution from external radiation.

In the case of the thyroid gland, the highest radiation doses are those received by infants because of the relatively small thyroid mass (assumed to be 2 g). The "maximum" individual (infant) is defined as a Richland infant drinking Richland water with radionuclide concentrations equal to those at the water plant and consuming food and milk obtained from commercial sources. Dietary assumptions for 1968 (table 19) were identical to those used in 1967.

The estimated thyroid dose received by such a Richland infant in 1968 was 110 mrem (7 percent of the appropriate standard) which is somewhat greater than the maximum infant thyroid dose for 1967 (97 mrem or 6 percent of the standard).

The slight increase resulted from an increase in the estimated dose contribution from iodine-133 in drinking water in 1968. Measurements of grab samples of drinking water taken monthly at the Richland water plant during 1968 indicated a somewhat higher ratio of concentrations of iodine-

133 to iodine-131 (6:1) than had been assumed for 1967 (4:1). The annual average iodine-131 concentration in cumulative samples multiplied by the iodine-133 to iodine-131 ratio was the estimated average iodine-133 concentration. Based on the 1968 values, the iodine-133 in drinking water contributed 58 percent of the "maximum" individual (infant) thyroid dose.

For comparison with the "maximum" Richland infant, the thyroid dose estimated for a Riverview infant consuming foods from the same sources as the adult "maximum" individual was 79 mrem in 1968. This lower value reflects the lesser contribution of iodine-133 in Pasco water compared to Richland water.

Table 21 shows the trend of "maximum" individual dose estimates for the period, 1964–1968. The 1968 thyroid dose and bone doses have been adjusted to a comparable basis (from iodine-131 only). The increase observed in the thyroid dose during 1966 reflects an unusual release of radioiodine to the Columbia River from a production reactor (*17*). The long-term trend for whole-body and GI-tract doses is obviously downward. Bone doses for the "maximum" individual are heavily dependent upon phosphorus-32 in Columbia River fish which are, in turn, dependent on river conditions as well as radionuclide release rates. The lower 1966 estimate compared to 1965 and 1967 reflects to some extent the extended reactor outage of that year. The decreases to 9 percent MPRI in 1968 resulted primarily from decreased concentrations of phosphorus-32 in Columbia River fish.

Table 21. Dose estimates for "maximum" individual 1964 to 1968[a]

Organ	Percent of standards					Standard (mrem)
	1964	1965	1966	1967	1968	
GI tract	9	6	5	5	4	1,500
Whole-body	18	8	7	6	5	500
Bone	[b]23	[b]12	[b]10	[b]12	[b]9	—
Thyroid (infant)	5	4	6	[c]3	[c]3	1,500

[a] Does not include fallout and natural background.

[b] For comparison, expressed as percent MPRI of ingested radionuclides rather than as percent of standard including dose from external sources.

[c] For comparison, includes dose from iodine-131 only.

The "typical" Richland resident

The majority of people who live in Richland obtain their food from local commercial stores (rather than from farms) and consume little or no Columbia River fish or local game birds. The principal source of radionuclides of Hanford origin ingested by such people is drinking water obtained from the Columbia River. For continuity with previous years, the doses for several organs of the body for the "typical" Richland resident have been calculated for 1968. Table 19 shows the dietary assumptions for this group.

The estimated dose to the GI tract of the "typical" Richland resident from nuclides of Hanford origin during 1968 was about 24 mrem or 5 percent of the maximum permissible dose, the same as in 1967. Ninety percent of the GI tract dose was contributed by drinking water. The combined doses from intake of bone-seeking nuclides and external exposure was 8 mrem or about 2 percent of the appropriate standard (500 mrem) for a suitable sample of the exposed population. Similar radionuclide intakes corresponding to about 1 percent MPRI were observed for 1966, 1967, and 1968. The estimated whole-body dose of the "typical Richland resident" for 1968 was 3 mrem or 2 percent of the appropriate standards, slightly less than for 1967.

For comparison, whole-body doses from natural background (excluded from the FRC guide) and from fallout in this region are estimated for the "typical" Richland resident at about 100 and 4 mrem/a, respectively.

For dose to the thyroid, the most appropriate sample of the exposed population would seem to be Richland infants. Table 19 lists the assumed consumption rates. The water is from the municipal system (assuming radionuclide concentrations equal to those at the water plant), the milk is from commercial sources, and a few leafy vegetables in season are obtained from local markets. From these sources, a thyroid dose for the "typical" Richland resident (infant) was 55 mrem, or about 11 percent of the appropriate standard, including an estimated contribution of 31 mrem from iodine-133 in the drinking water. For comparison, the calculated thyroid dose for 1967 from the same sources was 27 mrem for iodine-131 only.

Figure 8 shows the source and nuclide contributions to the doses to various organs for the "typical" Richland resident, and table 17 presents a dose summary.

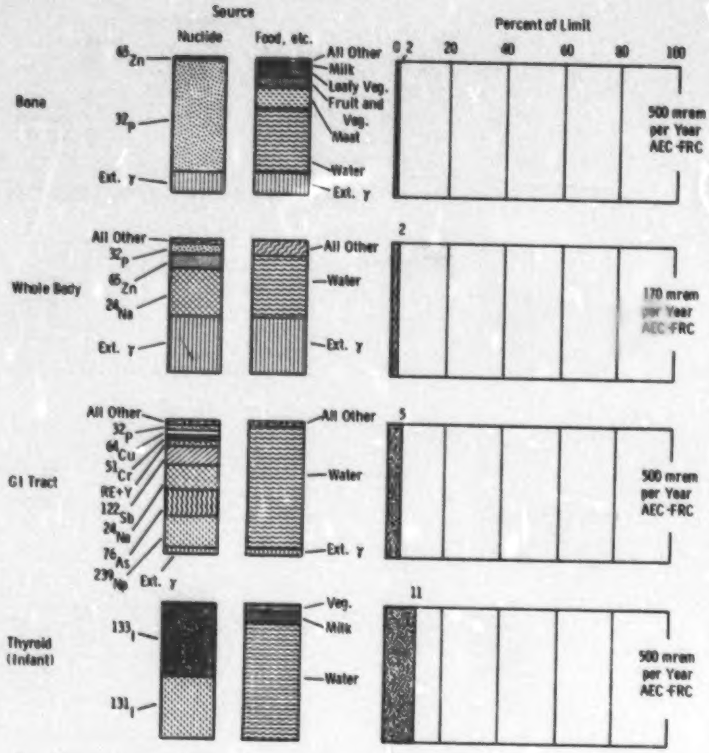

Figure 8. Estimated doses to the "typical" Richland resident, 1968

The "average" Richland resident

Estimates of average consumption rates of several food items were obtained for Richland adults from analysis of dietary questionnaires completed by plant employees. The program and the data have been discussed in another report (5). The principal changes from the consumption values assumed for the "typical" Richland resident were an increase of 55 percent for tap water (of which a substantial portion was consumed as coffee), a decrease of 58 percent for milk, a 75 percent decrease for seafood (one-tenth of which is still assumed to be Willapa Bay oysters), and the inclusion of 0.48 kg/a of Columbia River fish and 1.24 kg/a of game birds. Table 19 includes a summary of the "average" Richland resident's diet.

In computing doses for the "average" Richland residents, the assumed food sources were Richland drinking water with average concentrations adjusted for decay and dilution, Columbia River fish with the average species composition of fish ingested by the "maximum" individual, average game birds, milk, meat, and produce from local stores.

Because no significant contribution from Hanford operations to the background radiation levels in Richland can be discerned, the external dose to the adult "average" Richland resident is assumed to result only from recreational use of the Columbia River. An estimated annual dose increment slightly less than 2 mR from immersion in the river and activities along the shoreline was included in the GI tract, whole-body, and bone doses on the basis of a recent survey of Richland

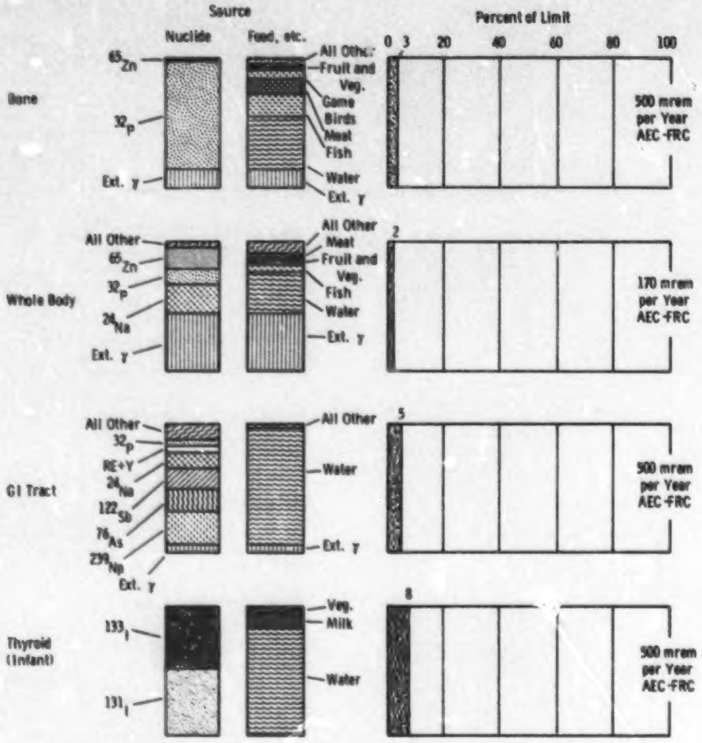

Figure 9. Estimated doses to the "average" Richland resident, 1968

teenagers and extrapolation of these data to the entire population.

The organ of the adult "average" Richland resident that received the highest percentage of the appropriate dose standard during 1968 was the GI tract at 25 mrem or 5 percent of the standard. The principal source (93 percent of the total dose) was drinking water. The whole-body dose from Hanford nuclides during 1968 was estimated to be about 3 mrem (2 percent of the standard), 46 percent of which resulted from recreational use of the Columbia River. The dose to bone was 13 mrem or about 3 percent of standard in 1968 including a dose from ingested radionuclides corresponding to about 1 percent MPRI in the terminology of past reports. About 41 percent of the total bone dose was derived from drinking water, 18 percent from fish, 13 percent from external radiation, 11 percent from meat, 8 percent from game birds, with 9 percent from remaining food items. A single radionuclide (potassium-32) accounted for 85 percent of the total bone dose. Dose estimates for the "average" Richland resident are illustrated in figure 9 and summarized in table 20.

As in the previous report, the infant "average" Richland resident was assumed to have the same food intakes and sources as were used for the infant "typical" Richland resident. However, use of an average composition of drinking water (adjusted for radioactive decay and dilution) resulted in a lower thyroid dose of 39 mrem or about 8 percent of the standard.

Conclusions

The results of the 1968 environmental surveillance program at Hanford again showed that the amounts of radionuclides as measured in the environs were well within accepted standards. The only estimates exceeding one-tenth of the appropriate standard were for the bone of the hypothetical "maximum" individual (17 percent of the 1,500 mrem/a standard) and for the thyroid of the infant "typical" Richland resident (11 percent of the 500 mrem/a standard). Because of changes in the method of computation, these dose estimates for the environmental population are not completely comparable to 1967 levels, but on a comparable basis they would represent a decrease. Process improvements and the shutdown of plant facilities both have contributed to a decrease in environmental doses from 1965 to 1968.

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Reported Nuclear Detonations, May 1971

(Includes seismic signals presumably from foreign nuclear detonations)

There were no nuclear detonations or seismic signals reported by the U.S. Atomic Energy, Commission for May 1971.

Not all of the nuclear detonations in the United States are announced immediately, therefore, the information in this section may not be complete. A complete list of announced U. S. nuclear detonations may be obtained upon request from the Division of Public Information, U. S. Atomic Energy Commission, Washington, D. C. 20545.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1971—[illegible]/11

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

RADIOACTIVE WASTE DISCHARGES TO THE ENVIRONMENT FROM A NUCLEAR FUEL REPROCESSING PLANT. *J. E. Logsdon and [illegible]. W. N. Hickey. Radiological Health Data and Reports*, Vol. *12*, June 1971, pp. 305–312.

The Nuclear Fuel Services fuel reprocessing plant has been in operation since 1966 and has provided valuable experience in waste management problems related to this type of facility. The large quantities of radioactivity which must be controlled at a nuclear fuel reprocessing plant virtually eliminate discharge-and-dilution as a satisfactory method of disposing of radionuclides which concentrate through environmental media. Radionuclides such as strontium-90, ruthenium-106, cesium-137, cesium-134, cobalt-60, tritium, and krypton-85 have been found in environmental media around NFS. These indicate that pathways to the public do exist as a result of operation of the facility. However, studies to date have indicated that typical population doses in the vicinity of NFS are not significantly different from doses received in other portions of the State.

KEYWORDS: Nuclear fuel reprocessing plant, radioactive waste, quality, environment, New York.

CHARACTERIZATION AND CERTIFICATION OF HEALTH PHYSICS TECHNICIANS. *R. L. Kathren. Radiological Health Data and Reports*, Vol. *12*, June 1971, pp. 313–317.

Personal, educational, and occupational history was obtained from a survey of more than 300 health physics technicians. The "average" technician is a 36-year-old married male with about 10 years of experience in the nuclear field. About two-thirds are veterans. Half of the group have completed two or more years of college, and most received specific training in radiological health on the job. Because of the diversity of educational and occupational backgrounds, a voluntary certification program is proposed, with certification requiring passage of a written examination in addition to several years of experience and other requirements.

KEYWORDS: Certification, health physics technicians, radiological health.

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